NCCWSC Plenary Powerpoint Presentations

December 3, 2008

Presentations on Science and Wildlife Management Dimensions

Dr. Katherine Hayhoe

HIGH RESOLUTION CLIMATE CHANGE PROJECTIONS FOR IMPACT ASSESSMENTS

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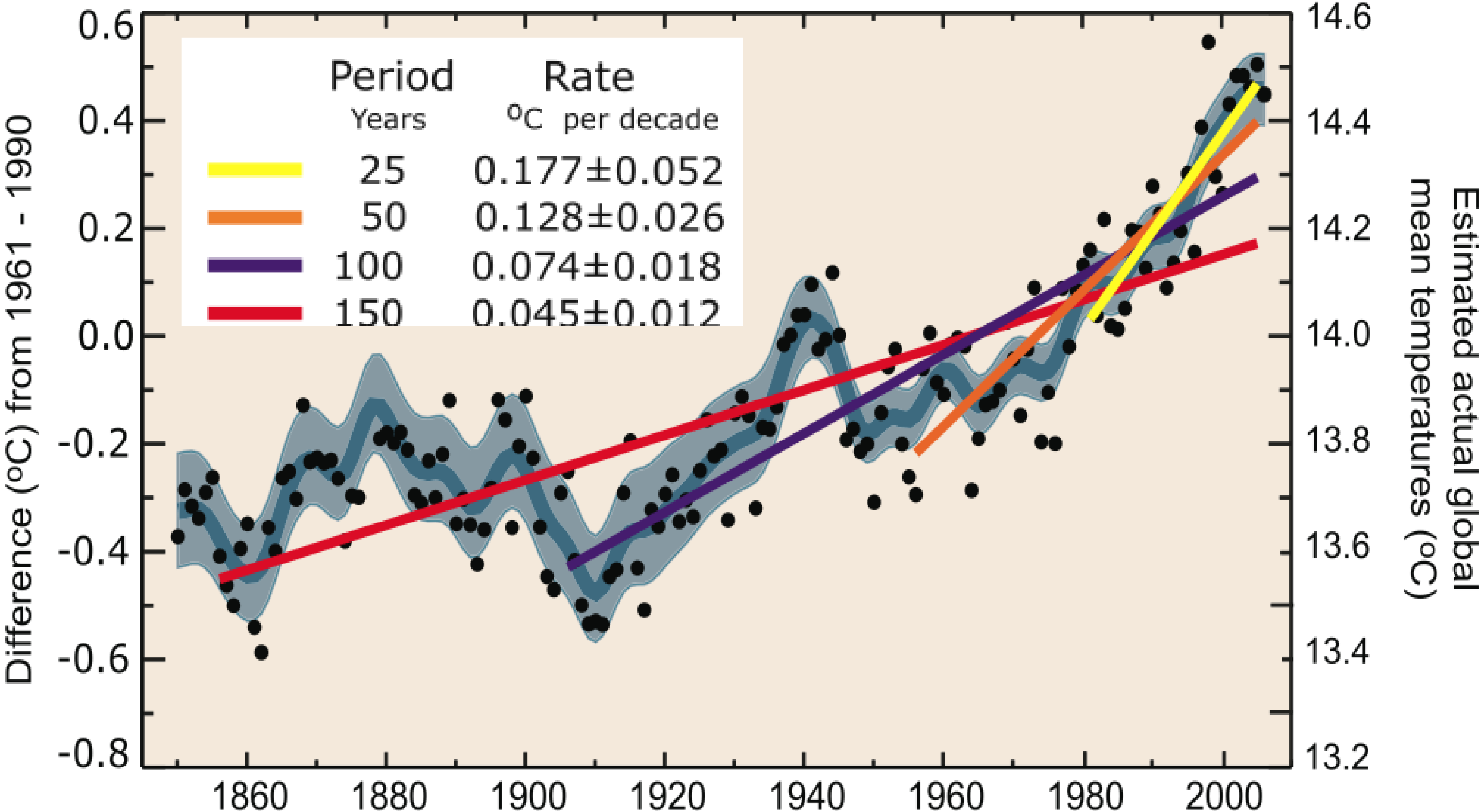
TEXAS TECH UNIVERSITY
ATMOS RESEARCH

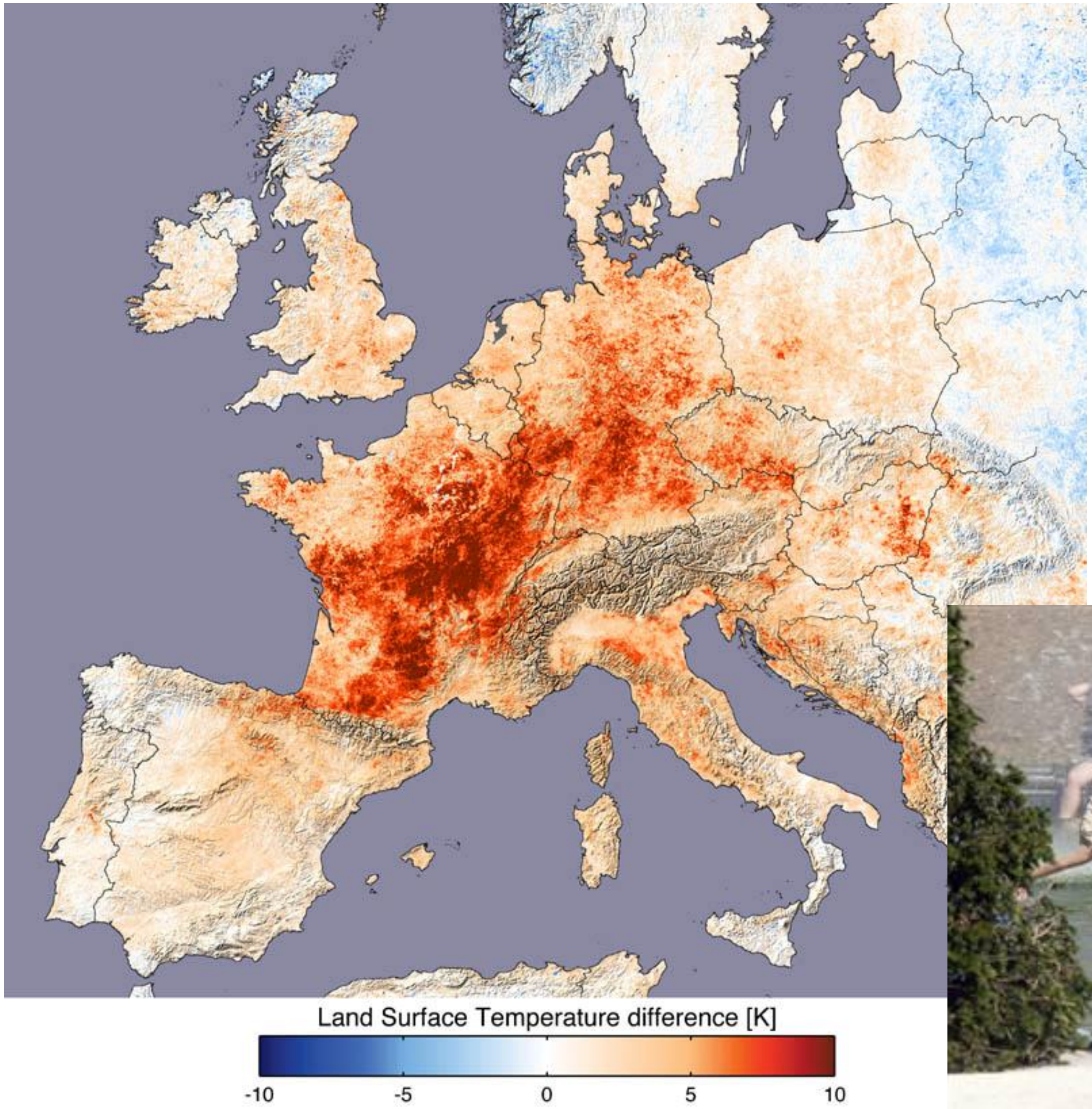
Three questions

- **Why** are climate projections necessary?
- **How** do we generate climate projections?
- **What** can we do with climate projections?

The planet is warming – faster and faster



Increased risk of extreme heat

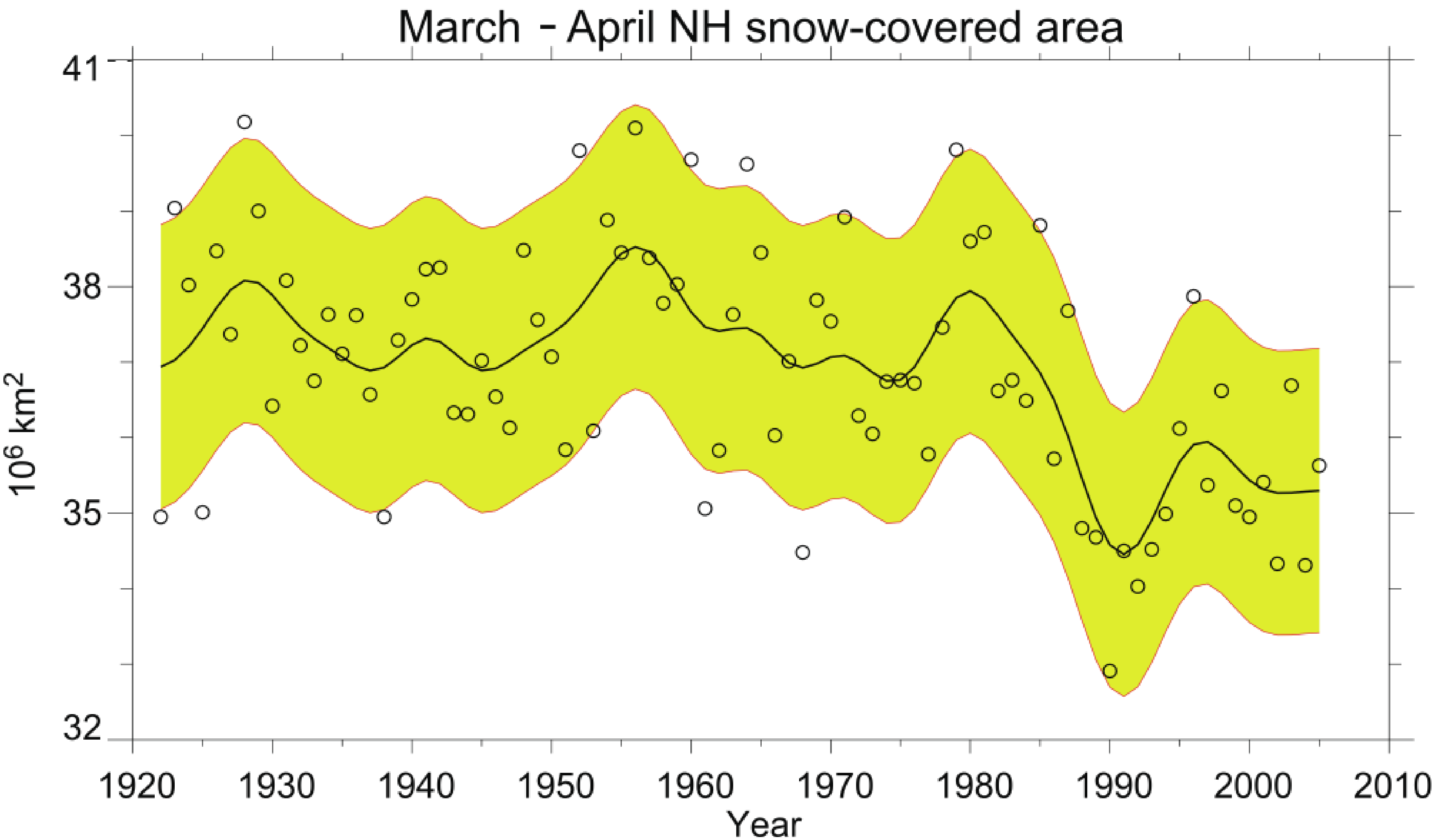


>70,000 deaths

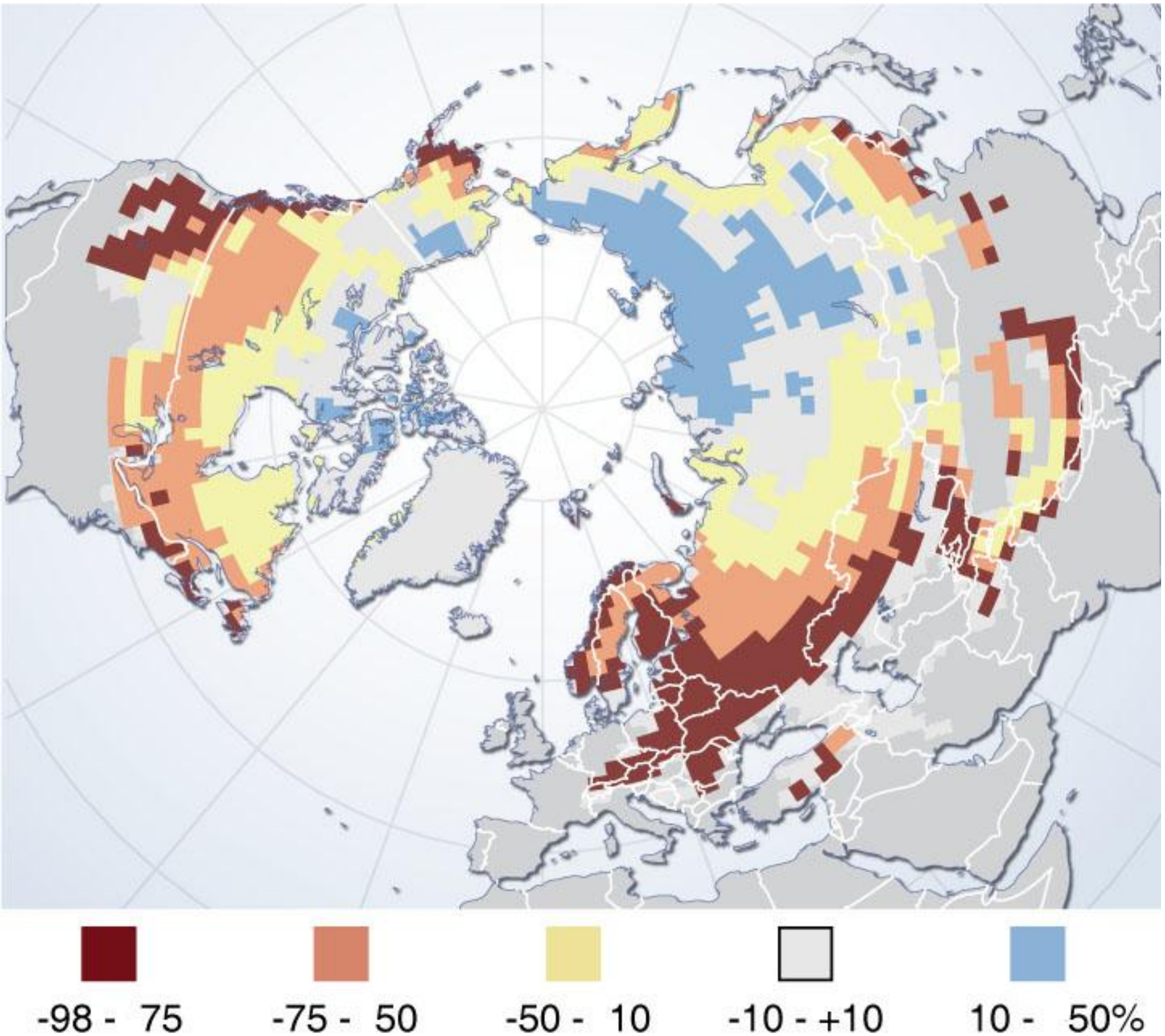
15% of Portugal's forests destroyed by fire (+18 deaths)

Flash floods in the Alps from melting glaciers

Snow-covered area is decreasing



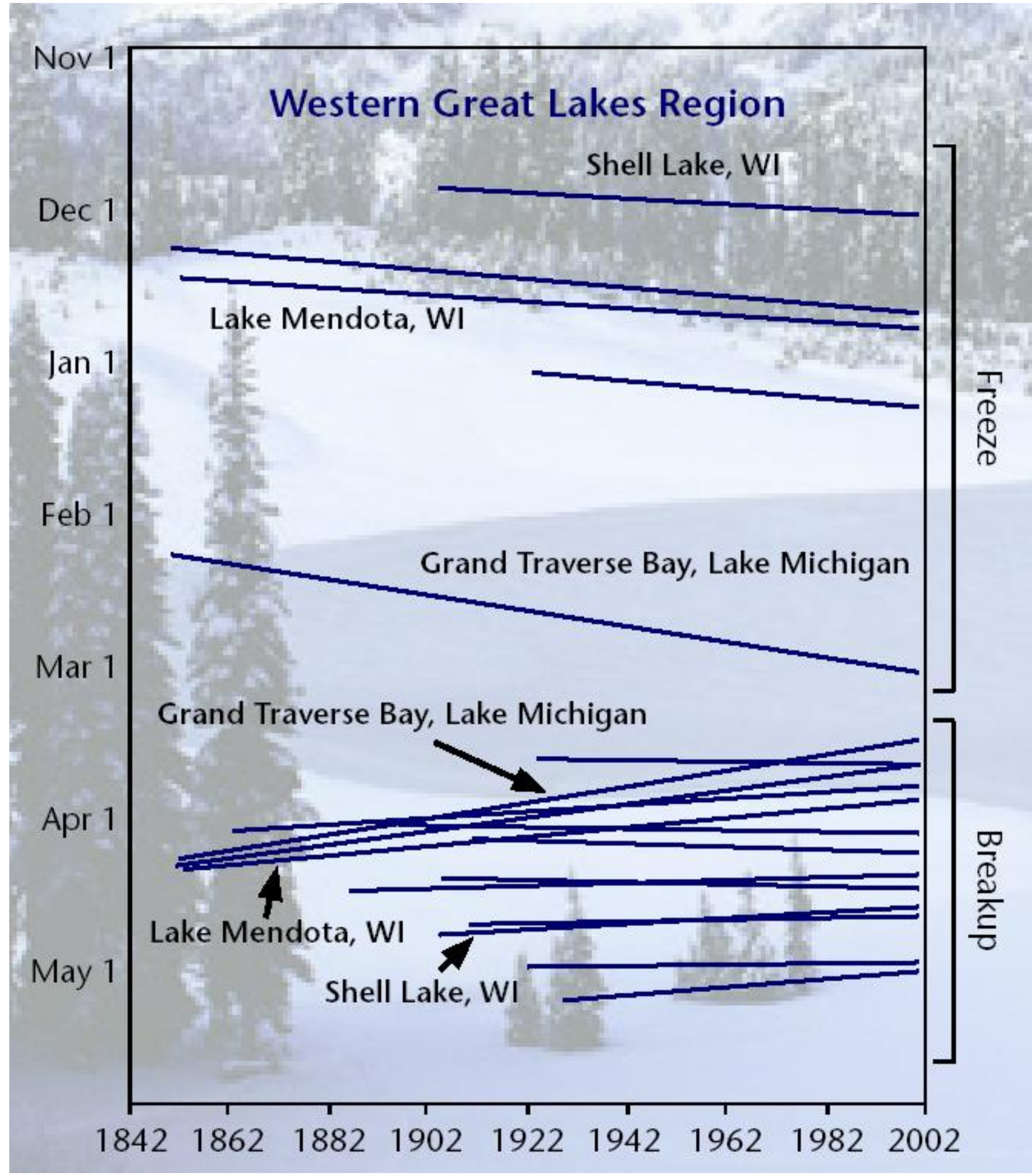
And is likely to continue to decrease



Percentage change from 1980-2000 to 2080-2100

Greatest changes at the 'edges' of the winter snow area

Ice cover on lakes is coming later and ending earlier



Glaciers are melting

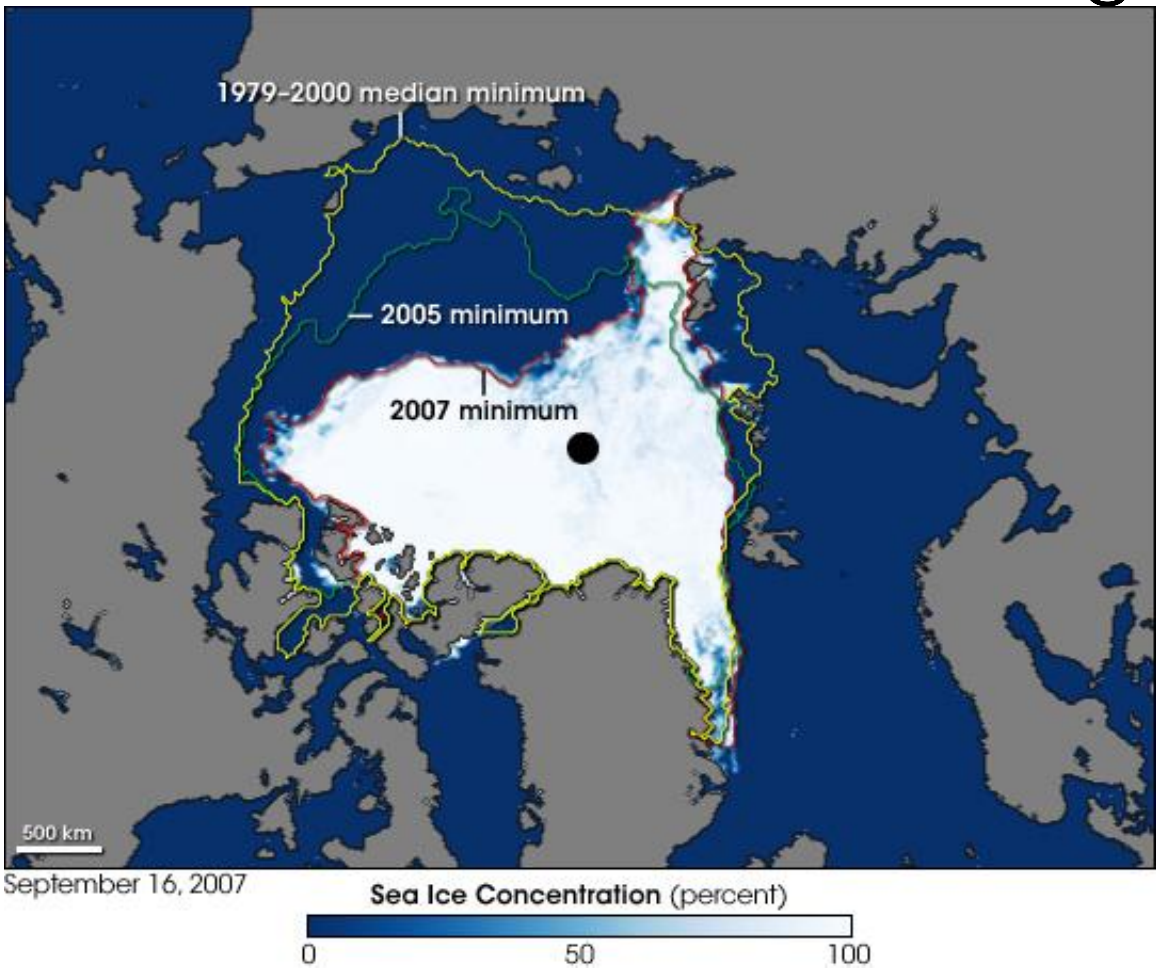
1913

2005

Shepard Glacier, Glacier National Park, USA (USGS)

By 2030, Glacier National Park could be glacier-free.

Arctic sea ice has been steadily decreasing



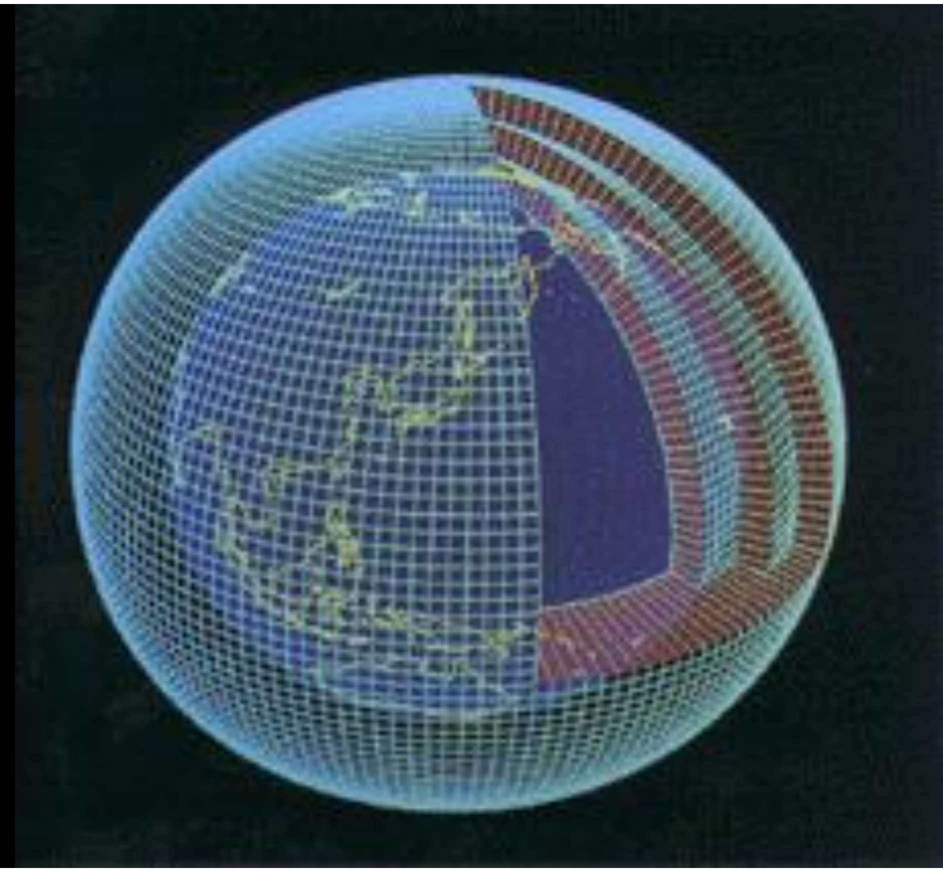
Over last 40 yrs:

- Summer sea ice extent decreased by 15-20% on average
- By 40% in 2007
- Ice-free summers likely within a few years

Three questions

- **Why** are climate projections necessary?
  - **Climate today is changing in ways that can’t be predicted by the past**
- **How** do we generate climate projections?
- **What** can we do with climate projections?

How do we know what to plan for?
Computer simulations of the earth system



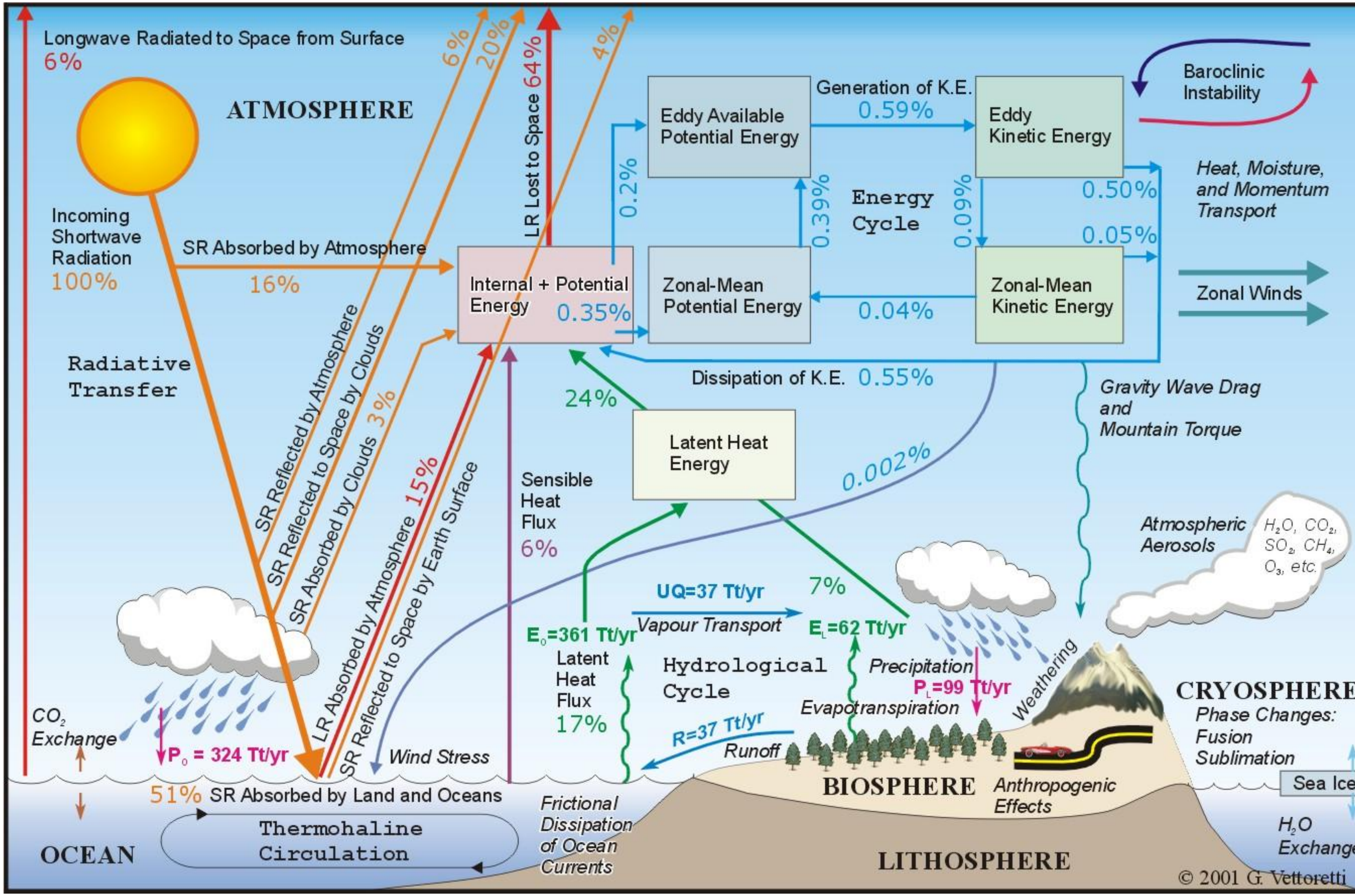
Based on physical governing equations

1. **Conservation of momentum** (F=ma for pressure differences and the Coriolis force)
2. **Hydrostatic equation** (how pressure varies with height - gravitational force balanced by pressure gradient force)
3. **Conservation of energy** (change in energy is equal to net transfer across boundaries by advection, evaporation, condensation)

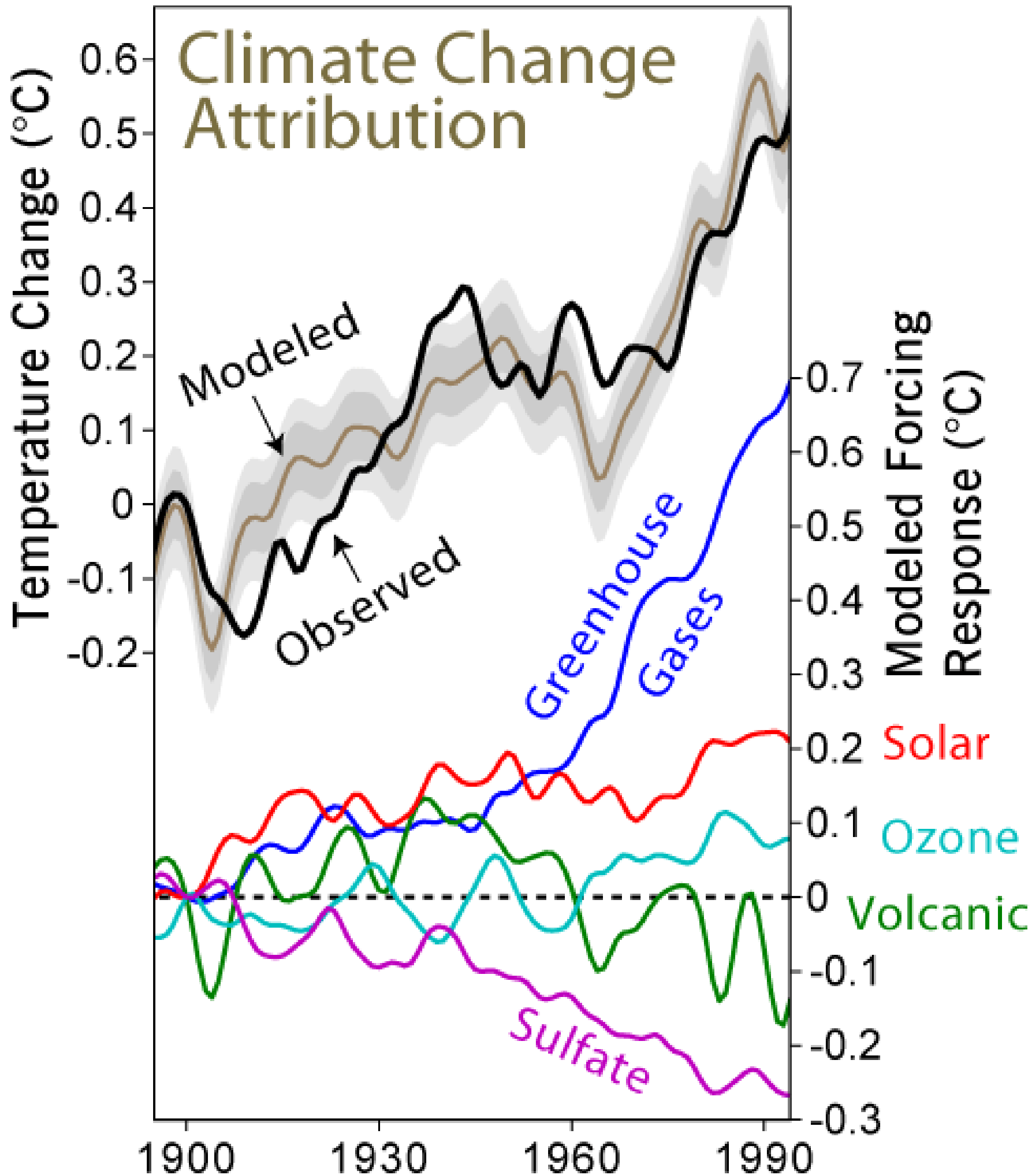
Based on physical governing equations

4. **Continuity equation** (conservation of mass – mass is neither created nor destroyed)
5. **Equation of state** (ideal gas law relates pressure, density and temperature)
6. **Water vapor equation** (accounts for changes in water vapour amounts due to advection, condensation, evaporation)

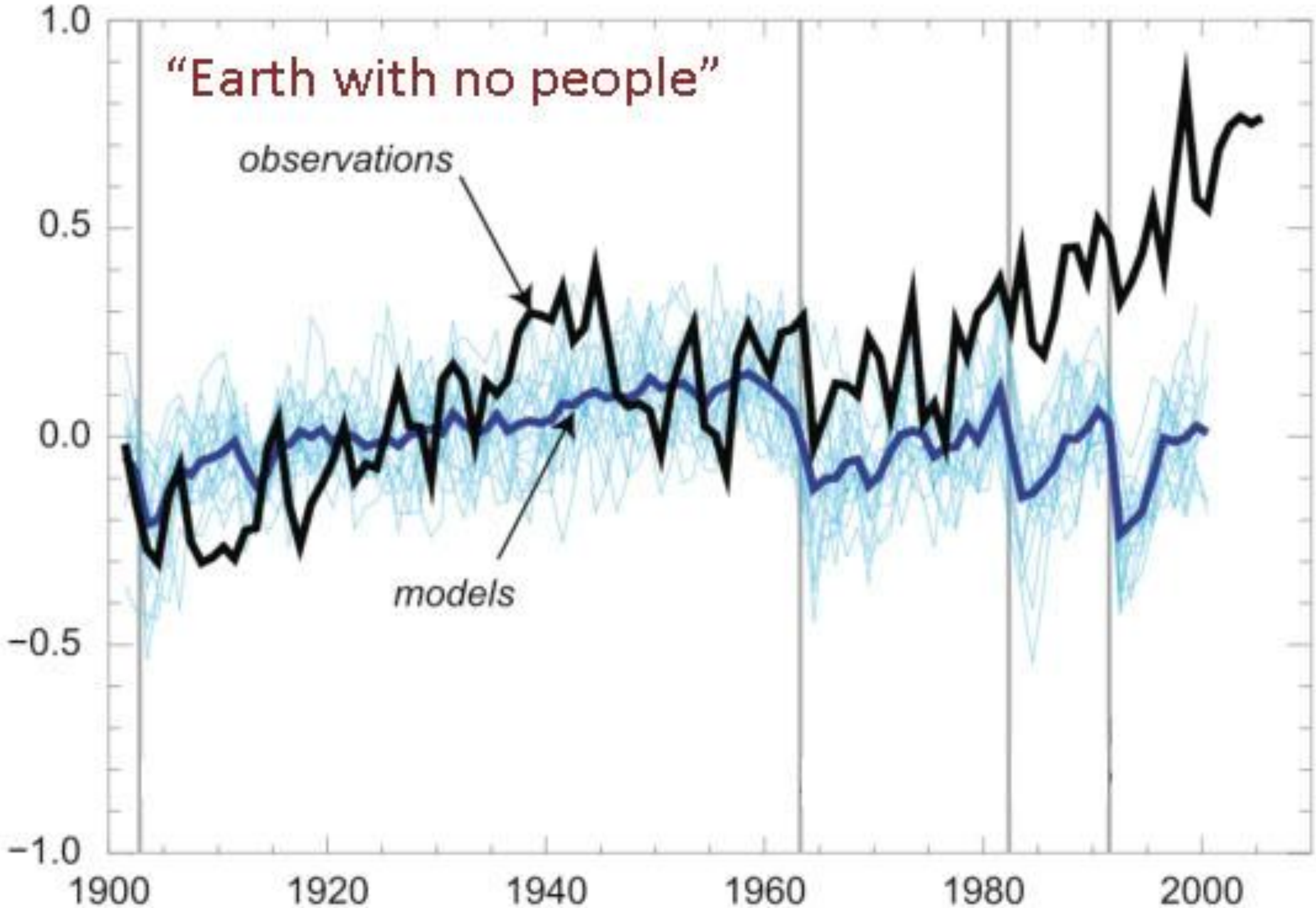
Modeling the climate system



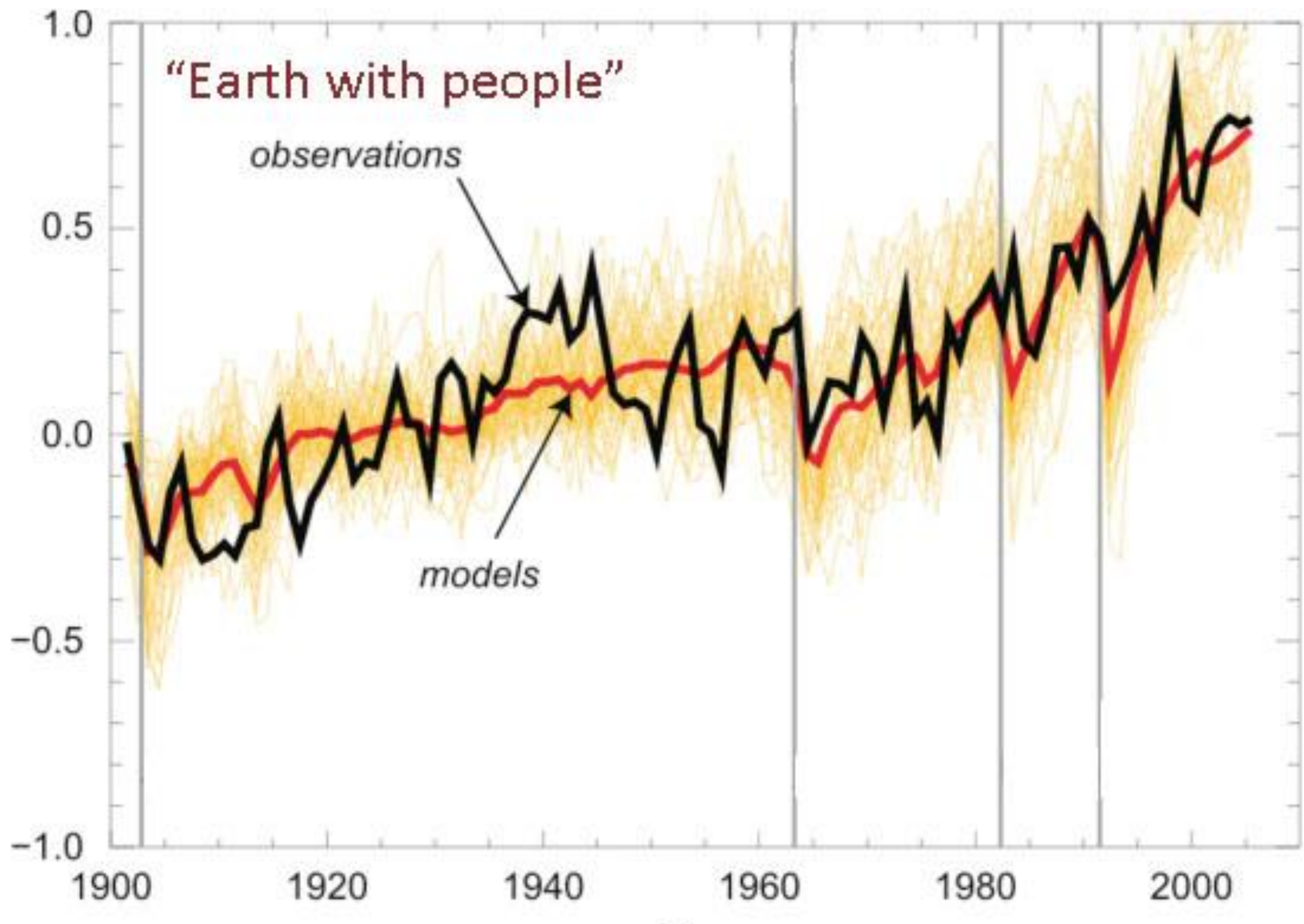
WHAT IS CAUSING CLIMATE CHANGE TODAY?



Quantifying the human influence

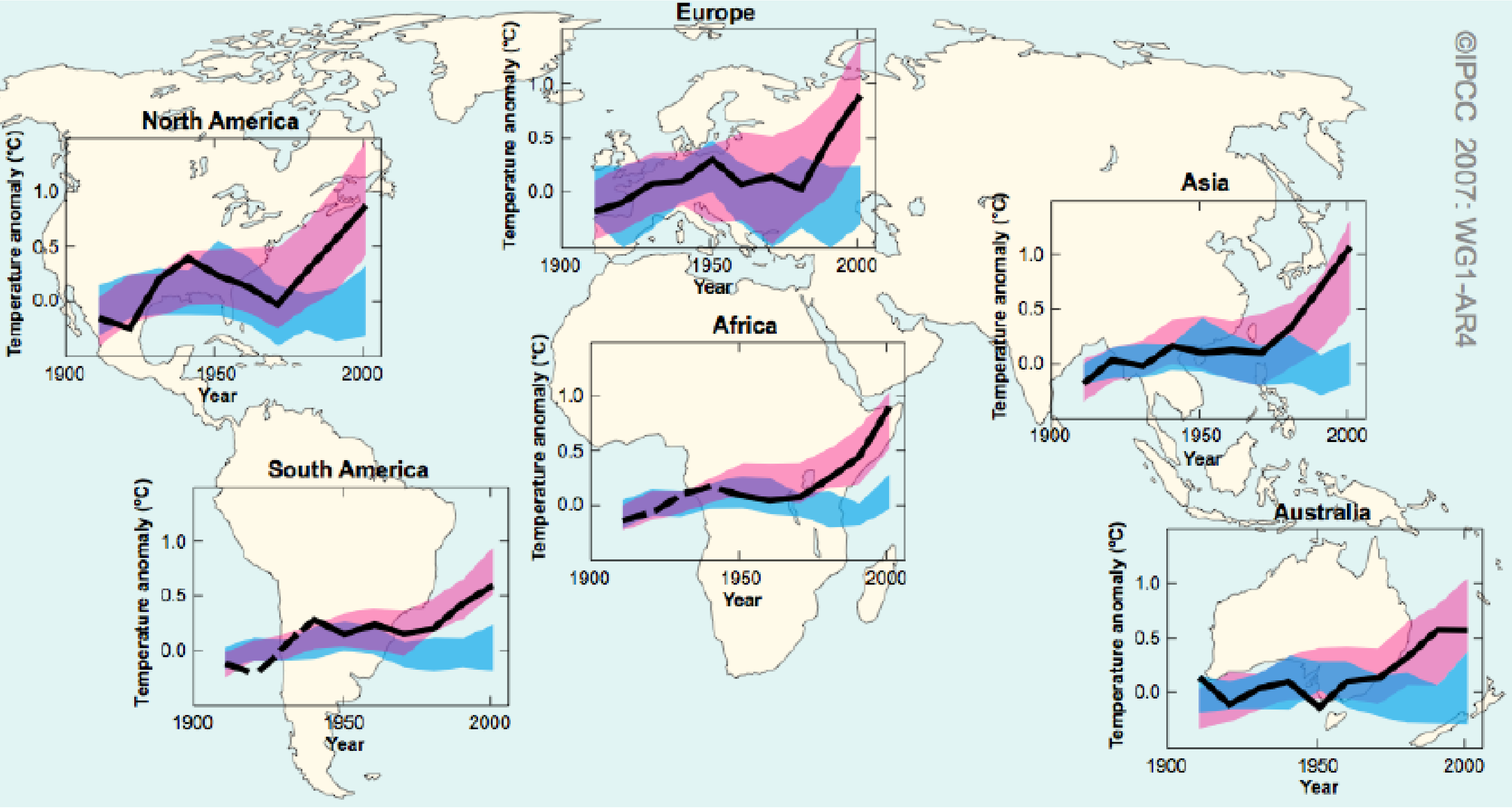


Quantifying the human influence



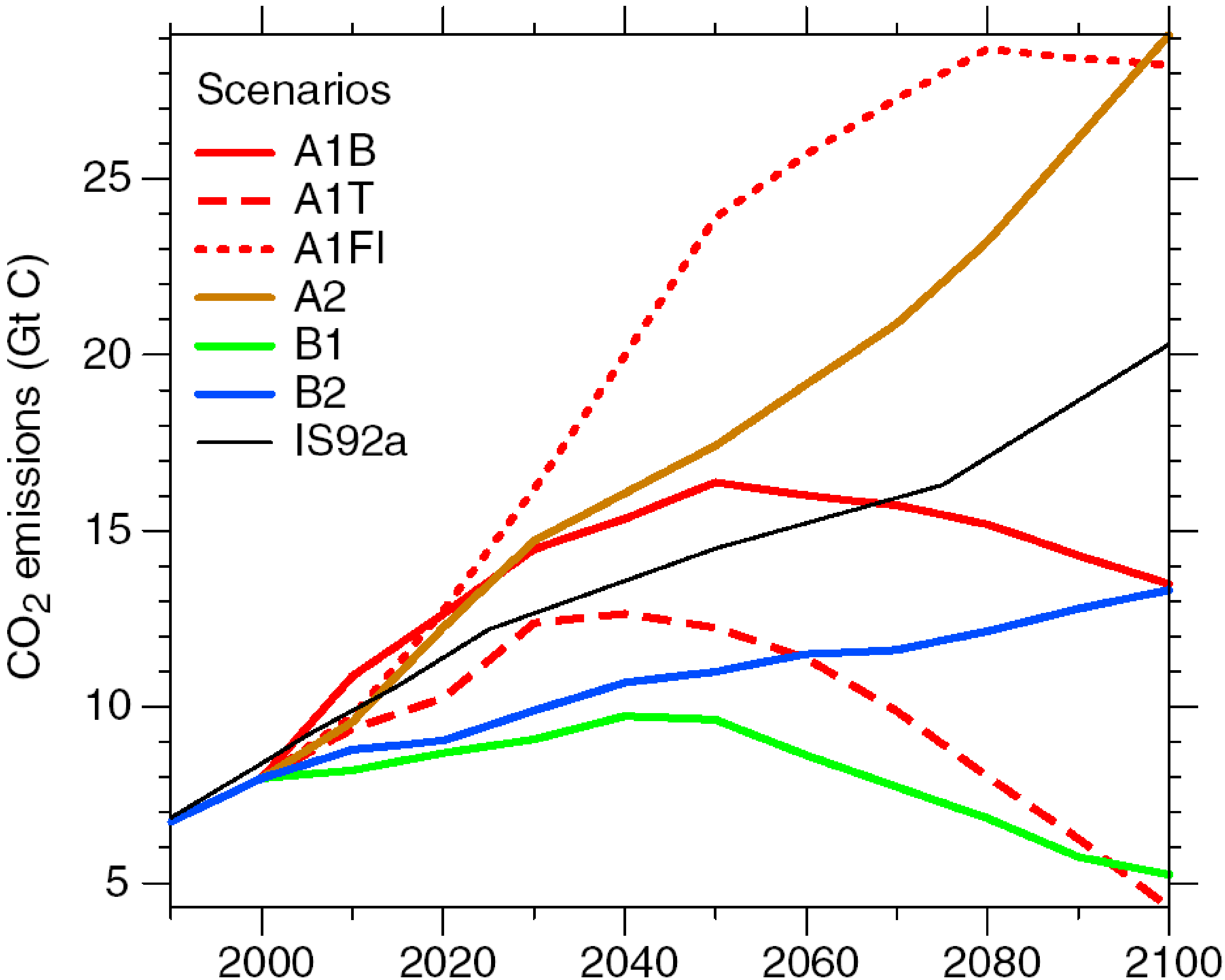
At the continental scale …

observations (black) natural (blue) natural + human (pink)
temperature increases from 1900 to 2000

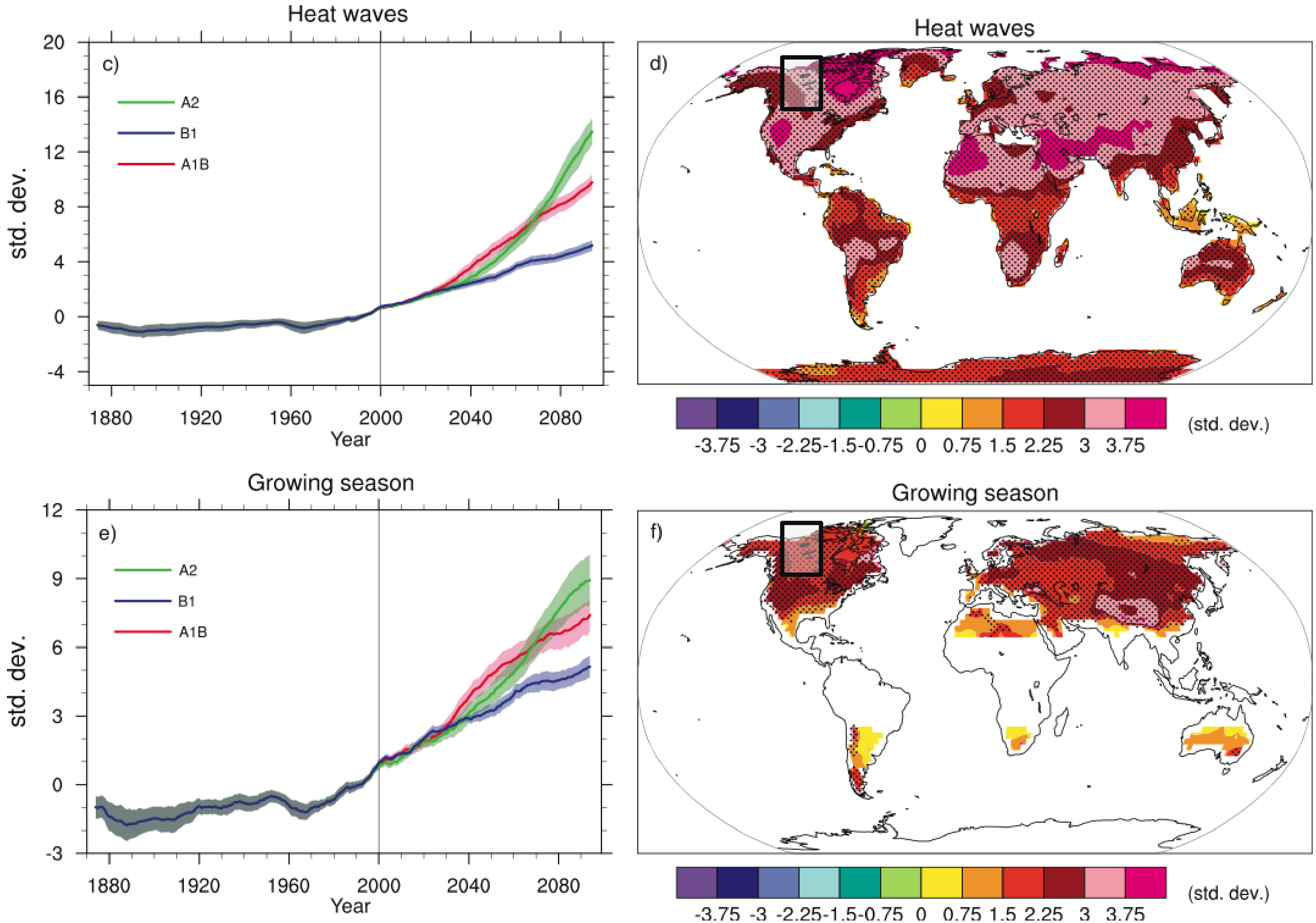


Into the future

Greenhouse gas emission projections

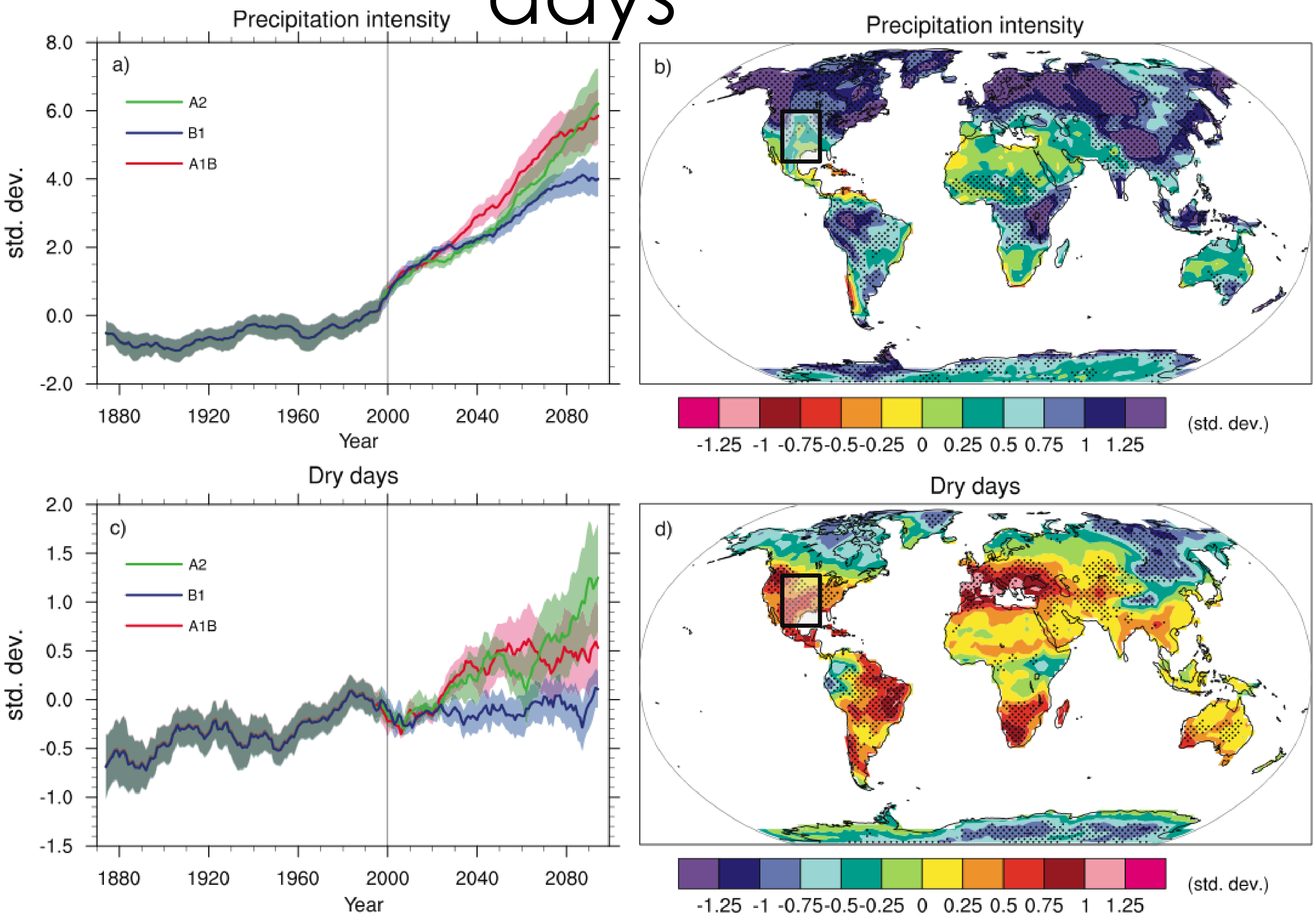


Heat Extremes and Growing Season

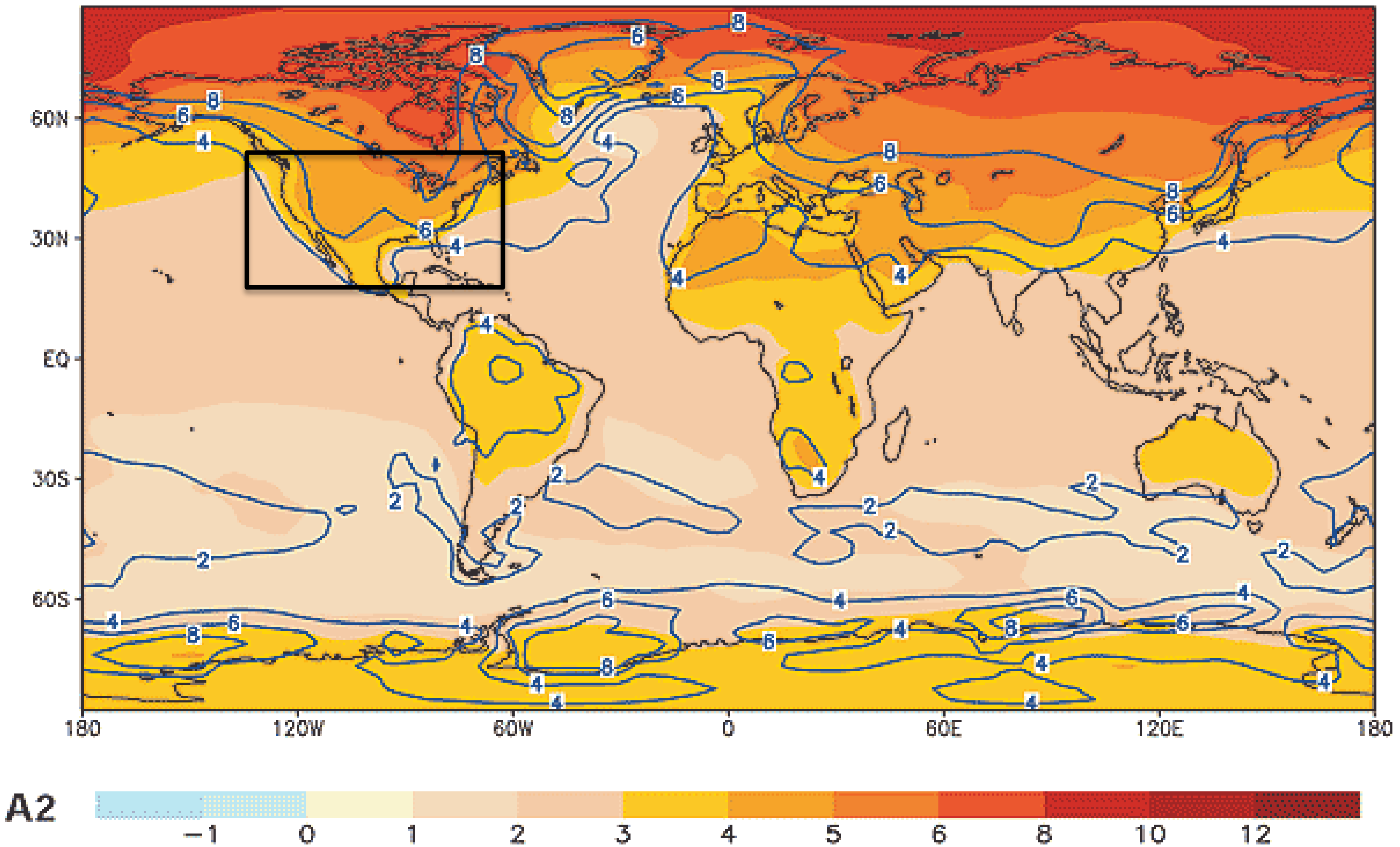


Intense precipitation and dry days

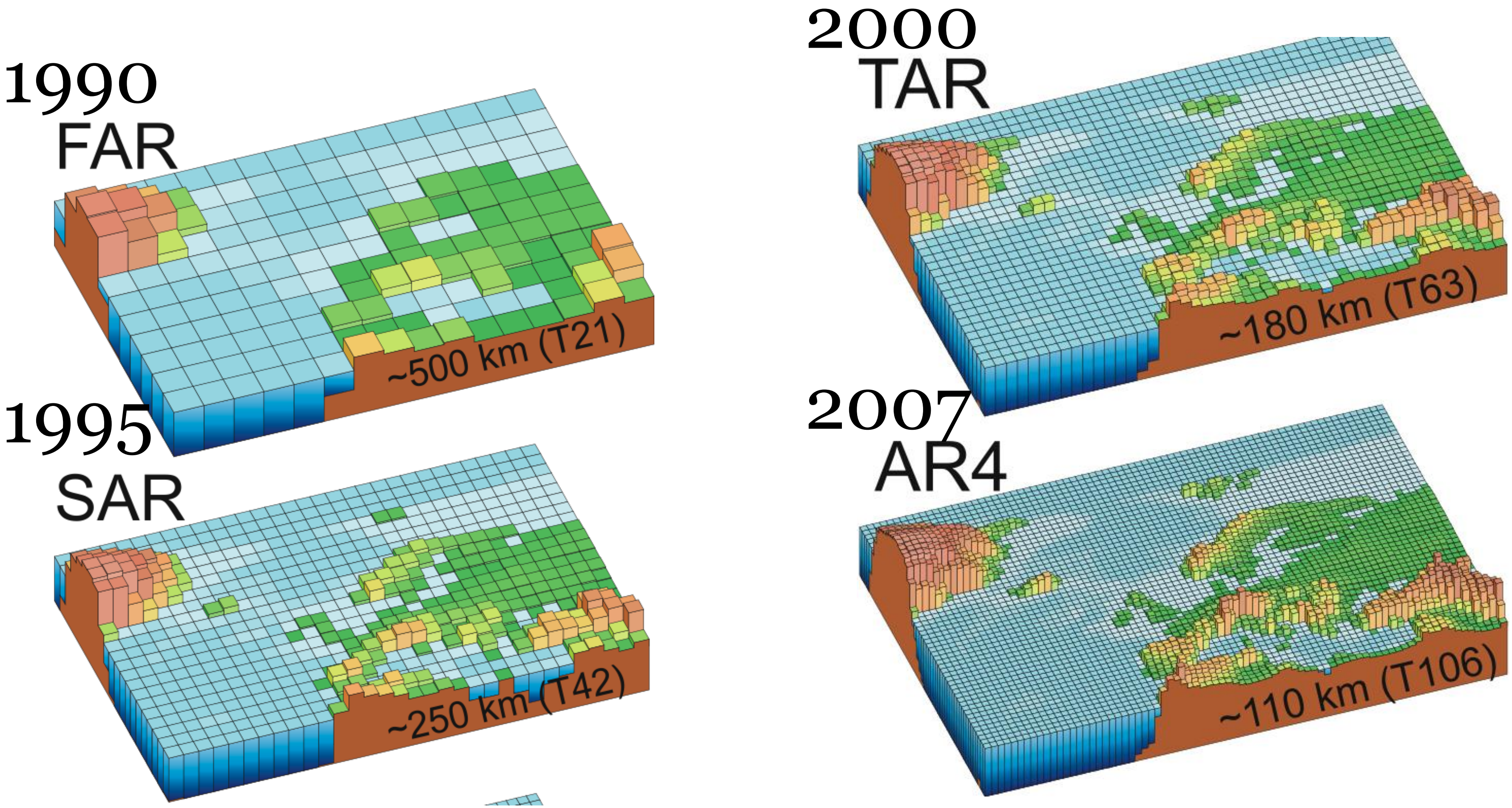
Precipitation Extremes



Why are regional projections needed?



CLIMATE MODEL GRIDS



Simulating sub-grid-scale climate based on output from global models

By developing a statistical relationship between local climate variables and global model predictors

By explicit solving of process-based physical dynamics of the regional climate system

STATISTICAL DOWNSCALING

From the individual farmer's field to grids as fine as <$1km^2$

Limited by the resolution of digital topographical maps & availability of observational data

Downscaling to individual point locations or high-resolution grids for impact analyses

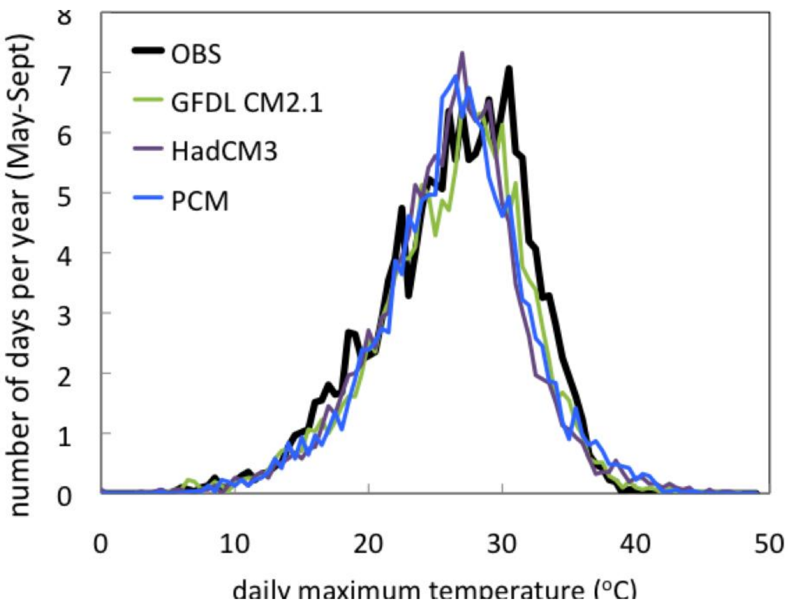
(agriculture, ecosystems, watersheds, urban air pollution & health)

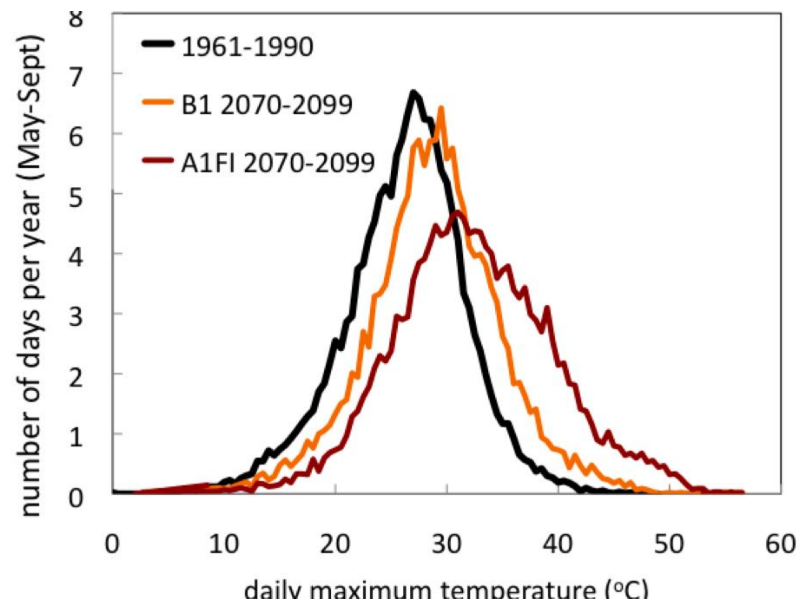
DYNAMIC DOWNSCALING

From $50km^2$ down to ~$10km^2$

Grids must currently be larger than ~2-$5km^2$ due to our limited understanding & parameterization of small-scale physical processes and limits on computing power

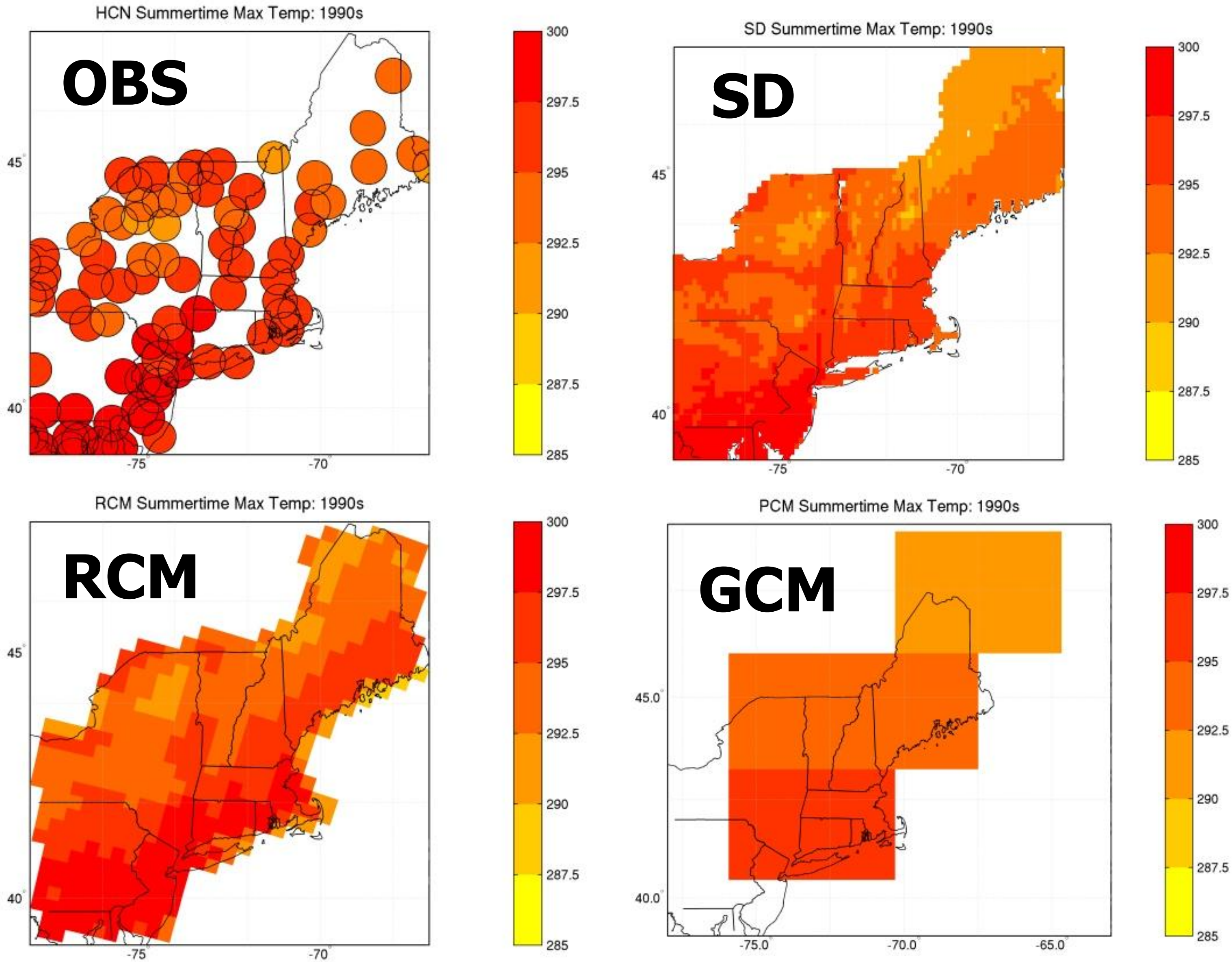
Statistical downscaling



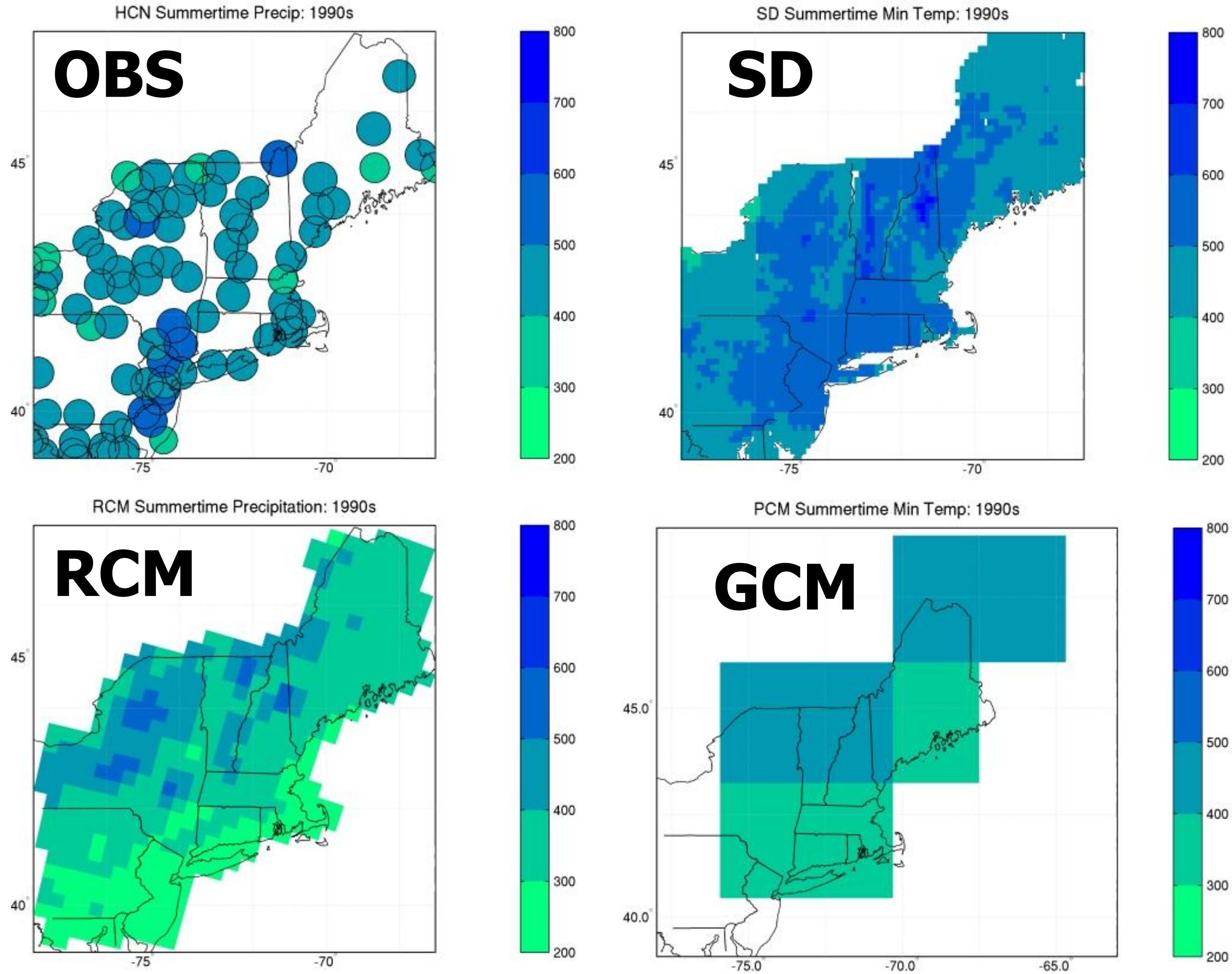


1. Assemble historical observations
2. Develop statistical relationship between model and observations
3. Test relationship using subset of historical data
4. Use relationship to generate future projections at the regional to local scale

Comparing regional models to statistical downscaling

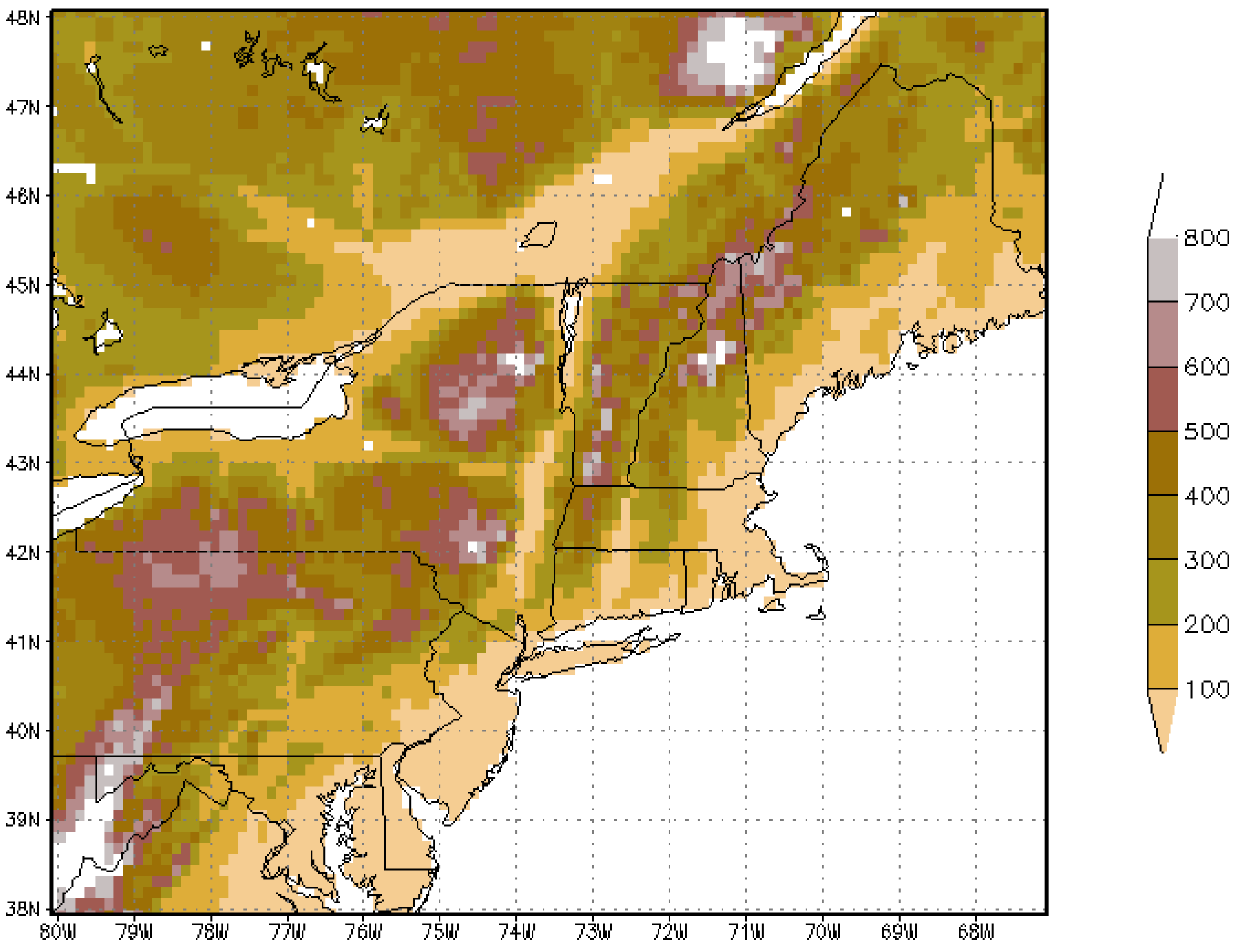


Comparing regional models to statistical downscaling



Three questions

- **Why** are climate projections necessary?
- **How** do we generate climate projections?
  - **Using state-of-the-art global climate models combined with the latest statistical and dynamical downscaling methods**
- **What** can we do with climate projections?



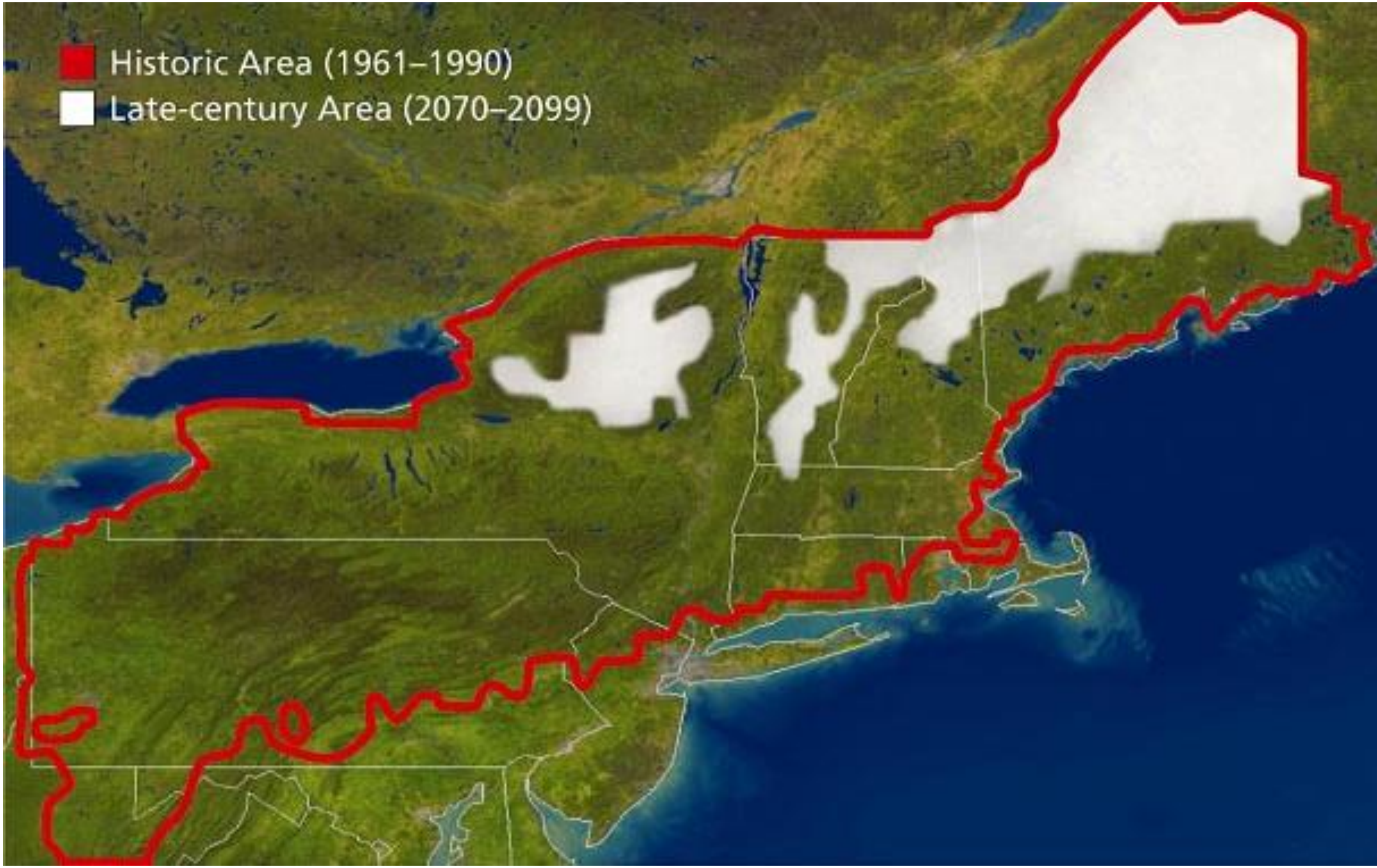
California

Northeast

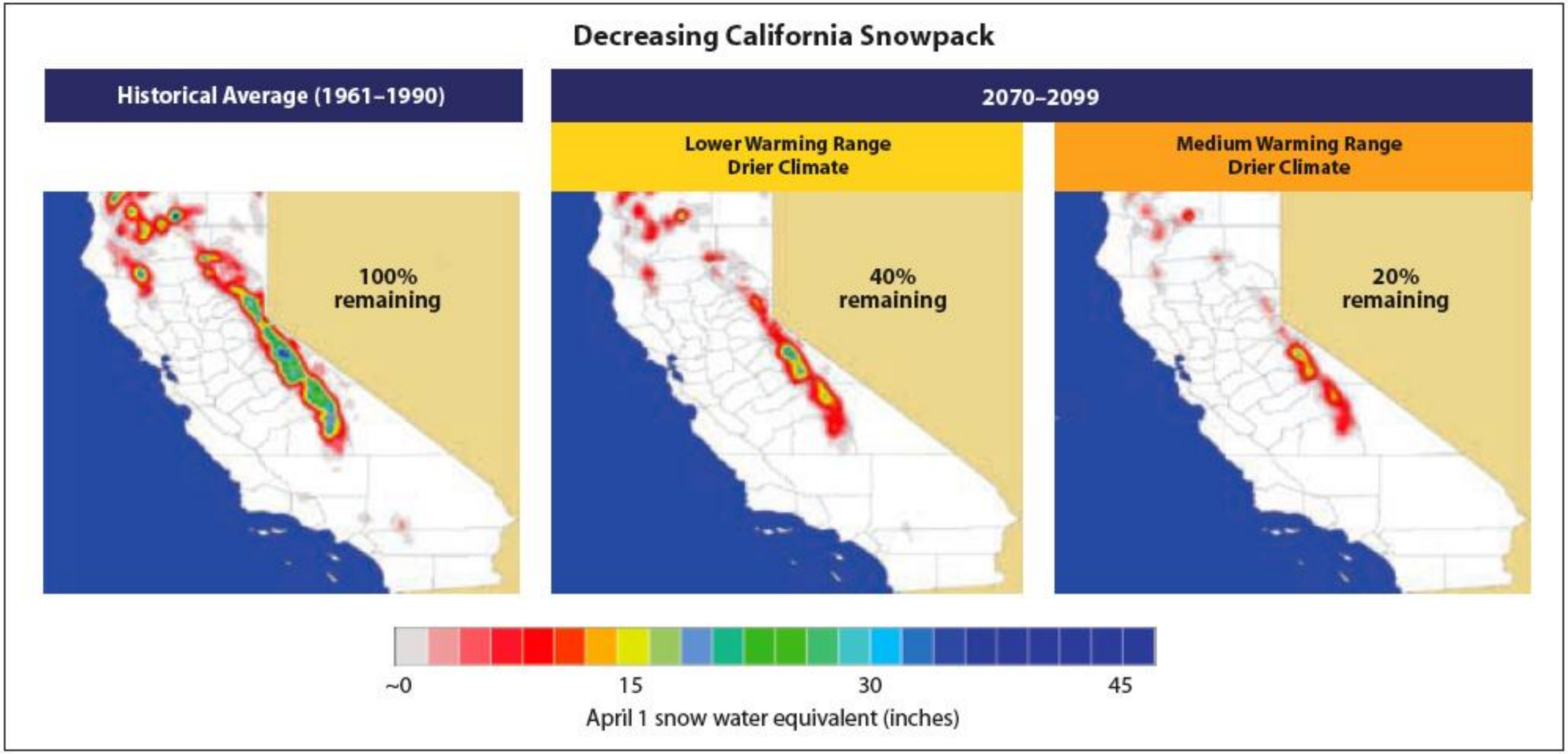
Great Plains Texas

Based on average summer daily maximum temperature and relative humidity

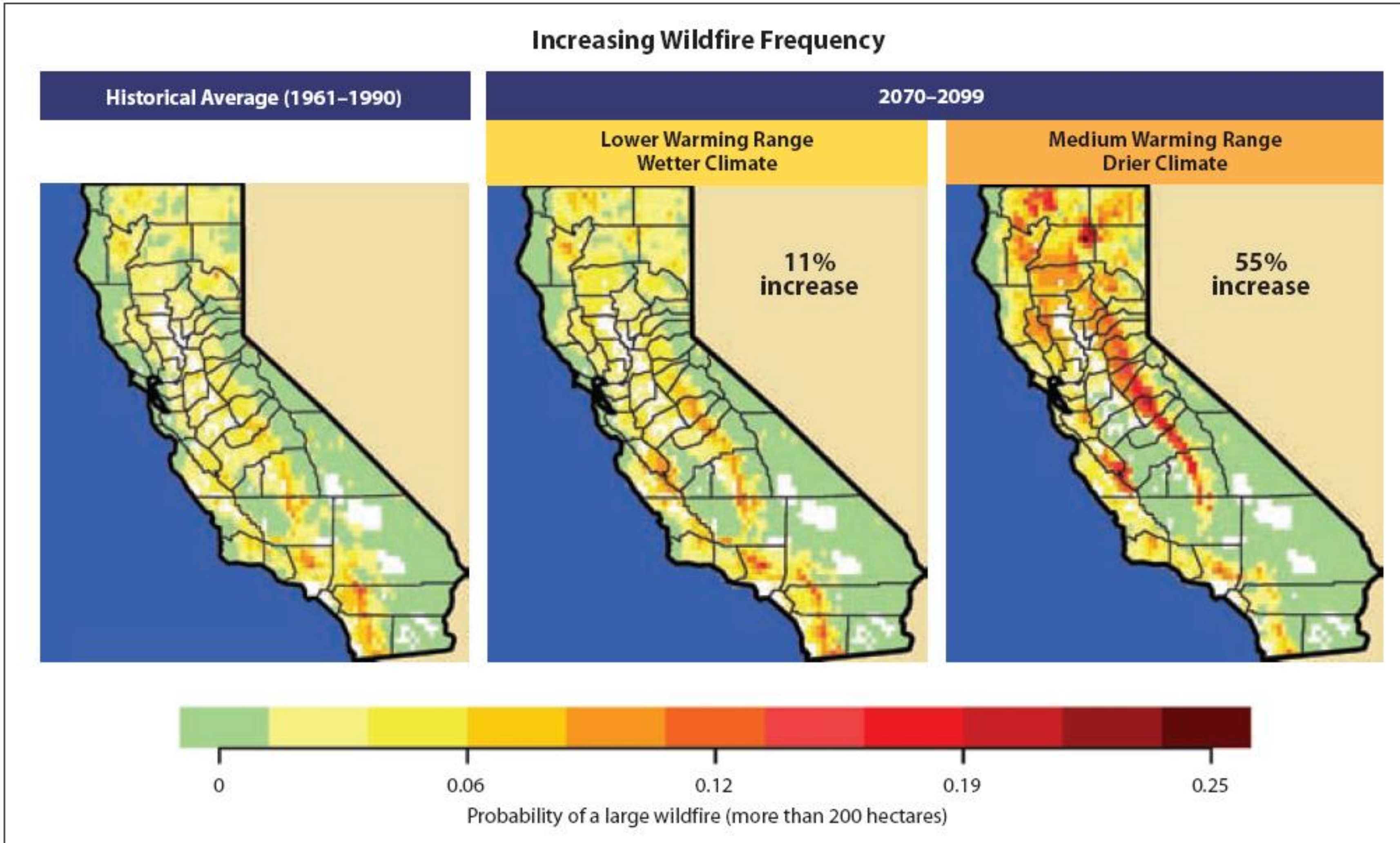
Snowcover in the Northeast



Decreasing California Sierra Snowpack

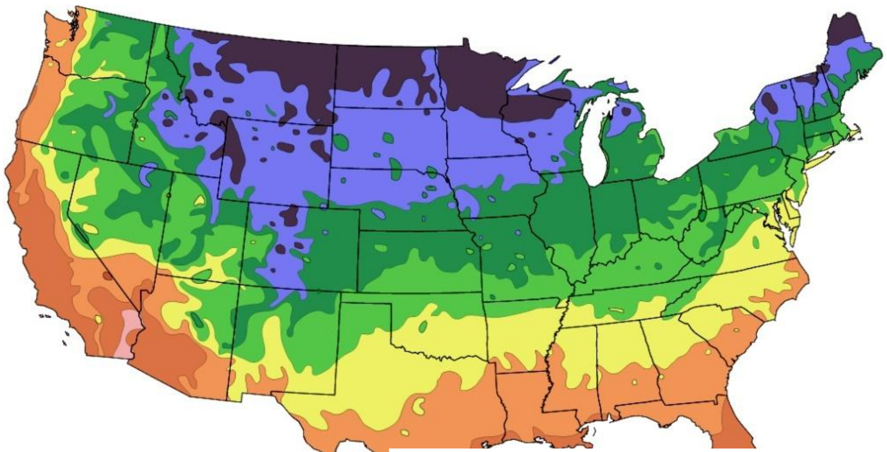


Increasing wildfire frequency

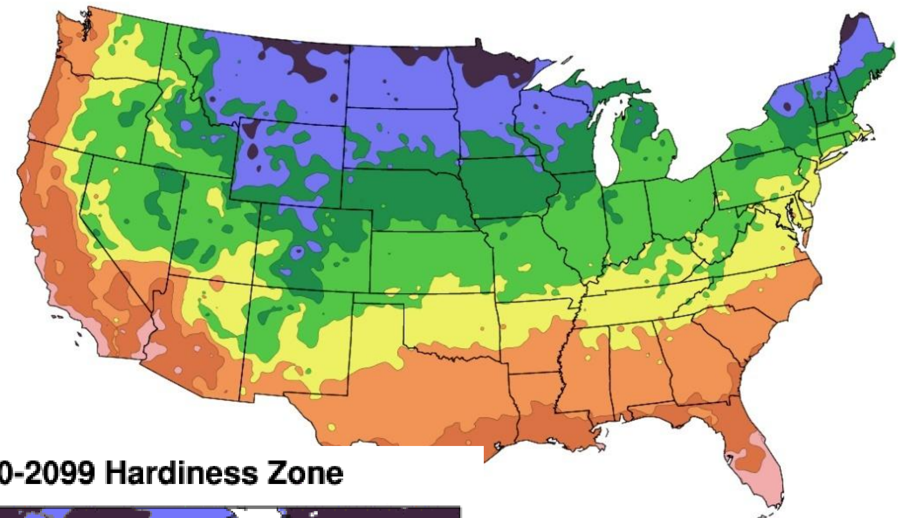


Shifting plant hardiness zones

1990 Map

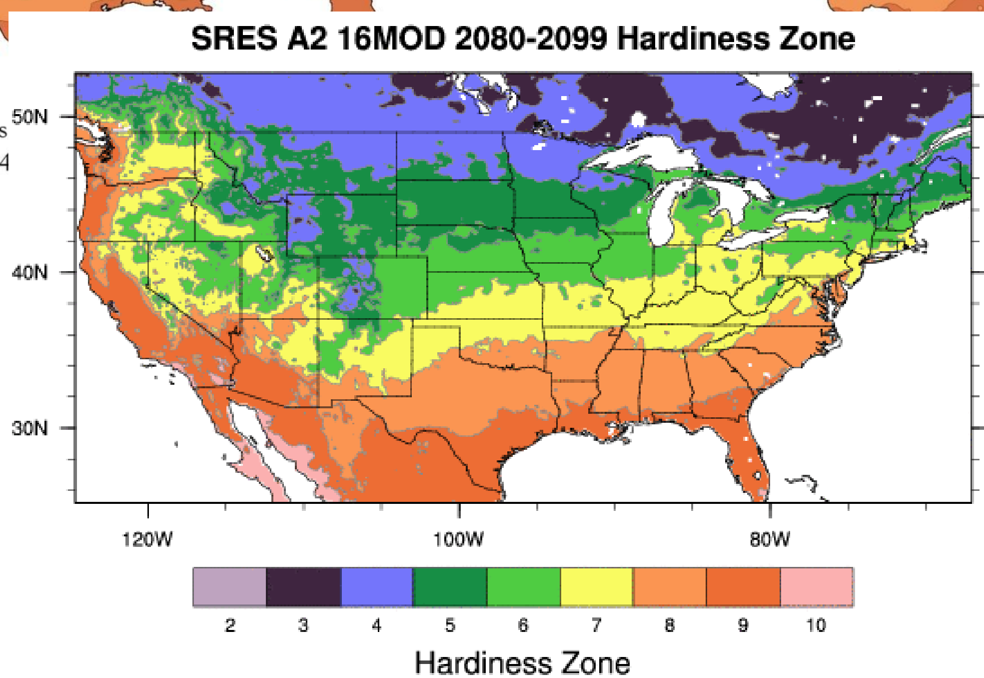


2006 Map

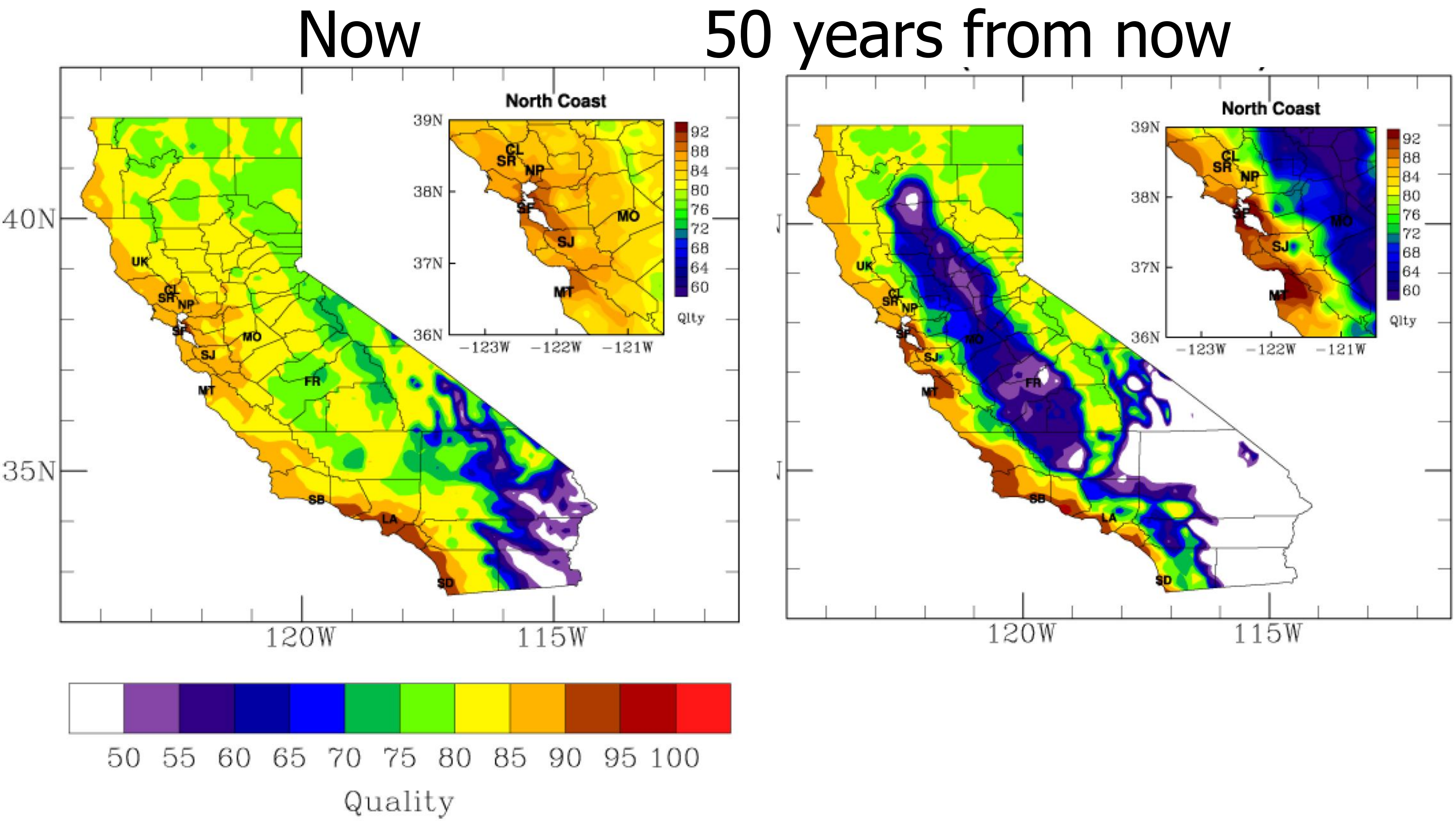


After USDA Plant Hardiness
Publication No. 14

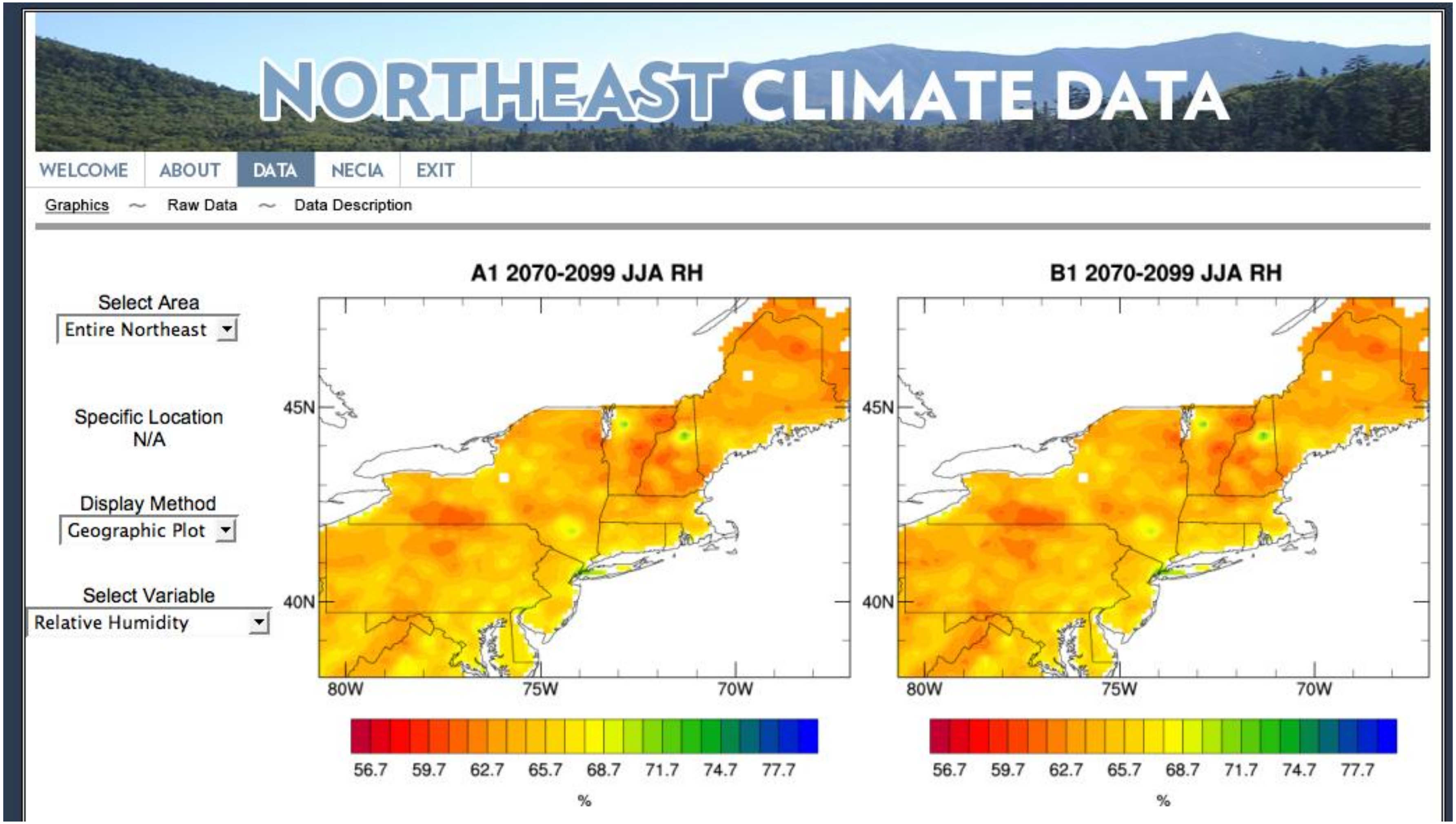
Plant Hardiness Zone Map
. 2006.



California Cabernet Sauvignon quality



… data available for analyses.



www.northeastclimatedata.org

Three questions

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  - Climate today is changing in ways that can’t be predicted by the past
- **How** do we generate climate projections?
  - Using state-of-the-art global climate models combined with the latest statistical and dynamical downscaling methods
- **What** can we do with climate projections?
  - Analyze the impacts of higher and lower emission pathways on anything from wildfire to wine grapes

THE END

FOR MORE INFORMATION
WWW.KATHARINEHAYHOE.COM

FOR SAMPLE DATA
WWW.NORTHEASTCLIMATEDATA.ORG

Presentations on Science and Wildlife Management Dimensions

Dr. Virginia Burkett

Habitat and Wildlife Response to Climate Change

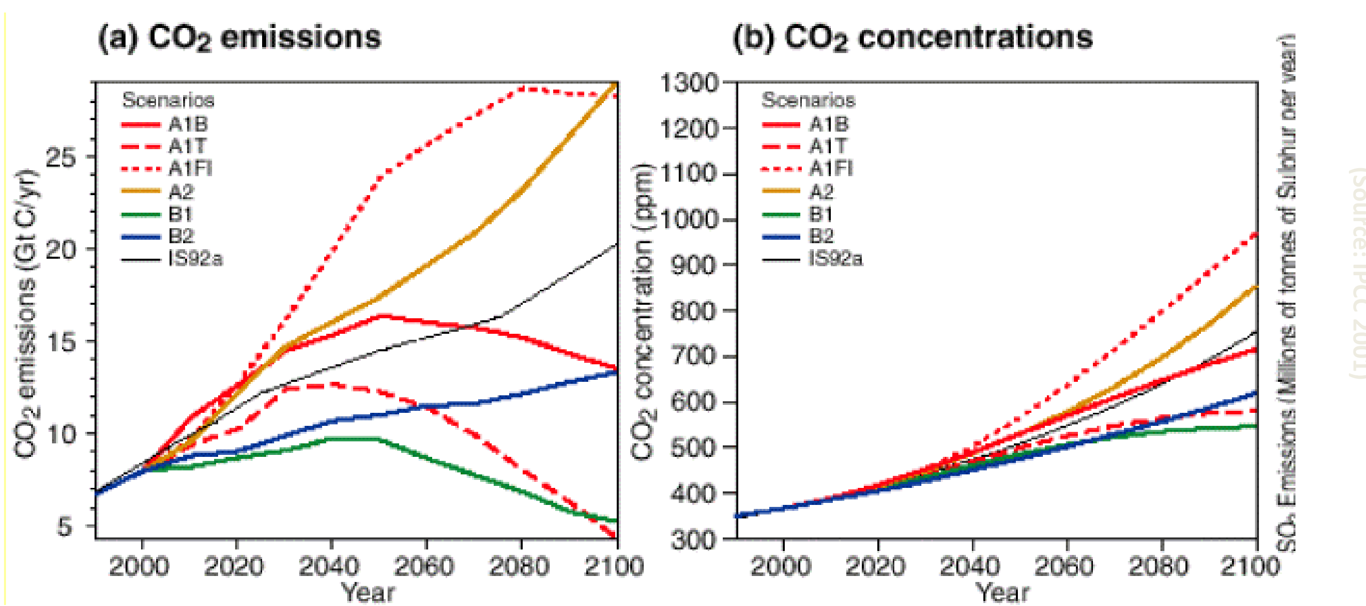
Virginia Burkett
Chief Scientist for Global Change Research
US Geological Survey

Outline

- Broad characterization of observed and anticipated changes in species and habitats
- Progress in capacity to forecast change
  - Examples of new tools and current approaches
- Complexities in predicting response – in supporting management
- Science and technology deficiencies

IPCC (2007) Key Conclusions Relating to Fish, Wildlife, and Habitats

- **During the course of this century the resilience of many ecosystems is likely to be exceeded by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification) and in other global change drivers (especially land-use change, pollution and over- exploitation of resources), if greenhouse gas emissions and other changes continue at or above current rates (high confidence).**



- **Ecosystems and species are very likely to show a wide range of vulnerabilities to climate change, depending on imminence of exposure to ecosystem-specific, critical thresholds** (very high confidence).

Temperature thresholds at which permafrost and sea ice thaw are key tipping points for Arctic ecosystems

An increase of 1°-2° C in summer ocean temperature maxima causes corals to bleach

- **With global average temperature changes of 2°C above pre-industrial levels many terrestrial, freshwater, and marine species (particularly endemics across the globe) are at a far greater risk of extinction than in the geological past** (medium confidence).

- **Globally ~20% to ~30% of species will be at increasingly high risk of extinction by 2100 if global mean temperatures exceed a warming of 2 to 3°C above pre-industrial levels** (medium confidence).

- **Substantial changes in structure and functioning of terrestrial, marine, and freshwater ecosystems are very likely to occur with a global warming of > 2 to 3°C above pre-industrial levels** (high confidence).

T ↑ 0.74°C past 100 yrs, T ↑ 0.65°C past 50 yrs

- **More evidence from a wider range of species and communities in terrestrial ecosystems and substantial new evidence in marine and freshwater systems show that recent warming is strongly affecting natural biological systems** (very high confidence)**.**
  - **poleward** and **elevational** range shifts of flora and fauna.
  - changes in the **timing of growth events**
  - changes in **abundance** of certain species

Bull Trout (FWS photo)

American Pika

N. American Wildlife – examples of observed changes in phenology and geographic range due to climate change

- Warmer springs have led to **earlier nesting** for 28 migrating bird species on the east coast of the U.S., earlier egg laying for Mexican jays and tree swallows.

- Red foxes have **expanded northward** in northern Canada, leading to retreat of competitively subordinate arctic foxes. In northern Canada, red squirrels breed 18 days earlier than 10 years ago.

- Several frog species now initiate **breeding calls 10-13 days earlier** than a century ago. Many frog species have **shifted their ranges**, typically to the north or to higher elevations.

- Edith's checkerspot butterfly - **locally extinct** in the southern, low elevation portion of its western range but extended its range 90 km north and 120 m higher in elevation.

Physical and biological systems on all continents and in some oceans are already being affected by recent climate changes, particularly regional temperature increases (very high confidence).

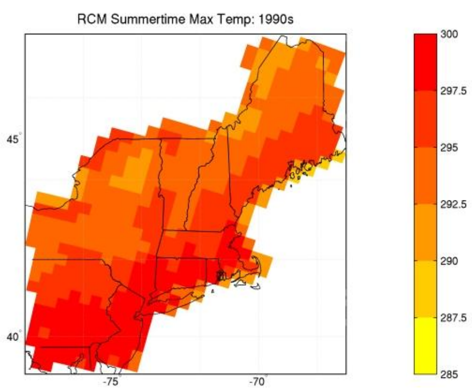
Climate change is strongly affecting many aspects of systems related to the cryosphere, emerging evidence shows changes in hydrological systems, water resources, coastal zones and oceans (high confidence)**.**

Current conservation practices are generally poorly prepared to adapt to this level of change, and effective adaptation responses are likely to be costly to implement (high confidence).

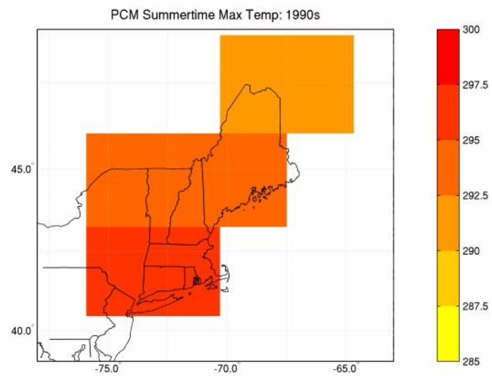



Emerging progress in predicting how changes in the physical climate system will affect fish, wildlife, and habitats

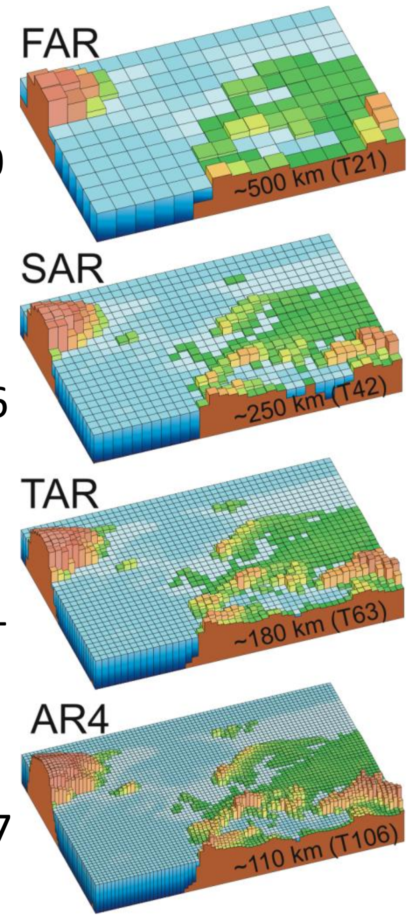
- Scale of climate models is moving towards scale of resource management



RCM



GCM

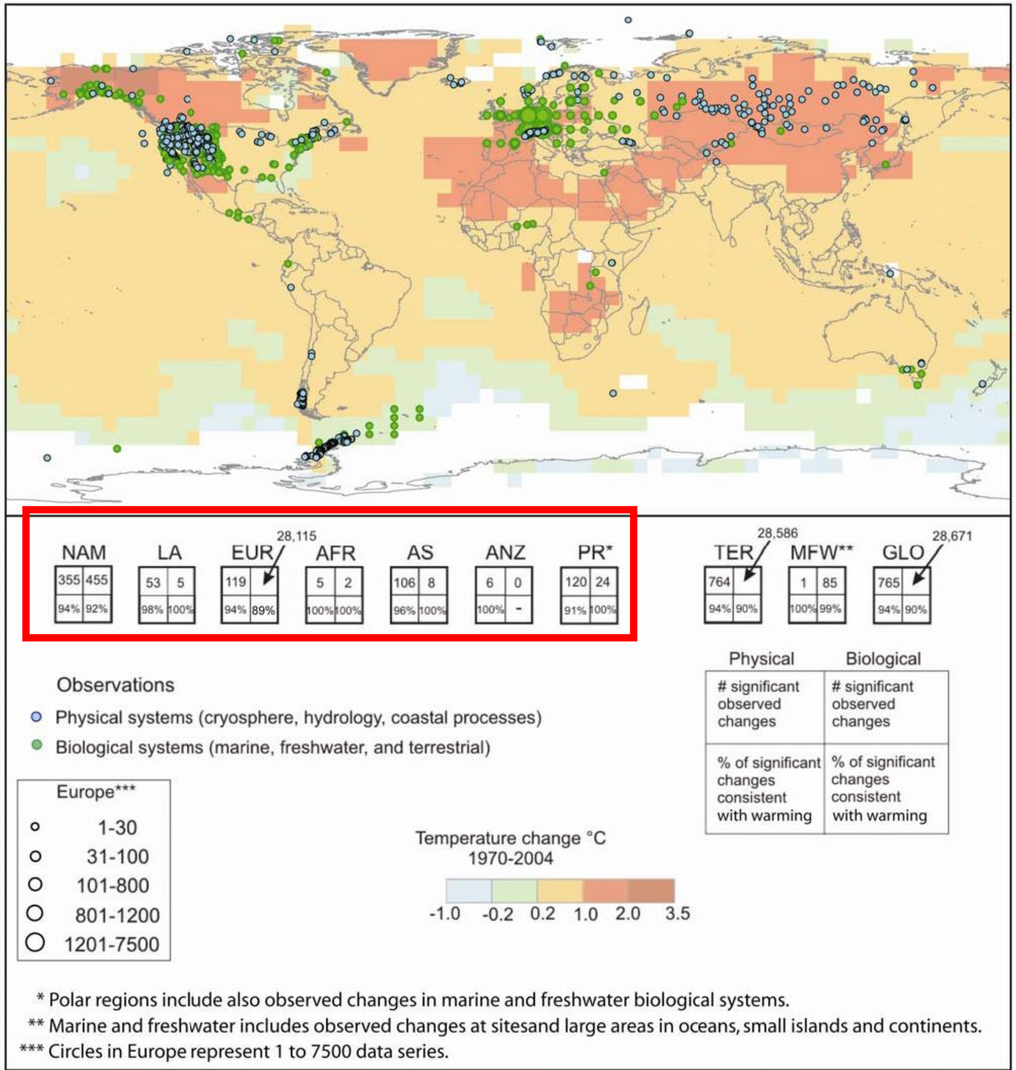


1990
1996
2001
2007

Emerging progress in predicting how changes in the physical climate system will affect fish, wildlife, and habitats

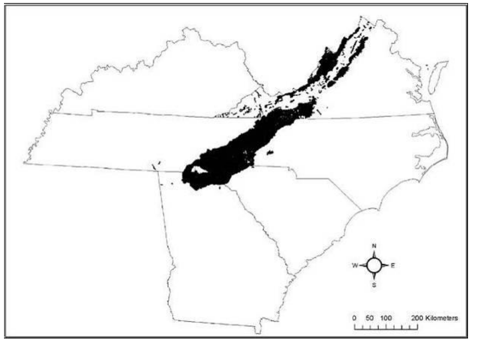
- Scale of climate models is moving towards scale of resource management
- Thousands of species- and ecosystem-specific records of observed change have increased the knowledge base for simulating wildlife impacts

(IPCC WG II, 2007)

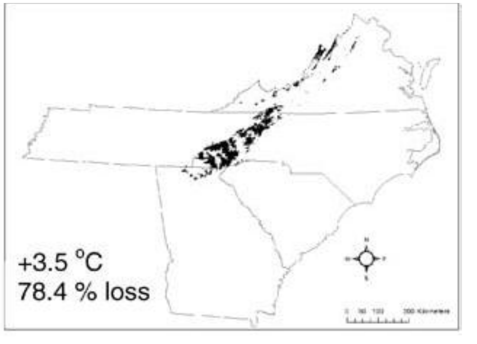


Emerging progress in predicting how changes in the physical climate system will affect fish, wildlife, and habitats

- Scale of climate models is moving towards scale of resource management
- Thousands of species- and ecosystem-specific records of observed change have increased the knowledge base for simulating wildlife impacts
- Scenarios of future change have been produced for some species and biomes



Current Distribution of Wild Brook Trout



Predicted Distribution of Wild Brook Trout

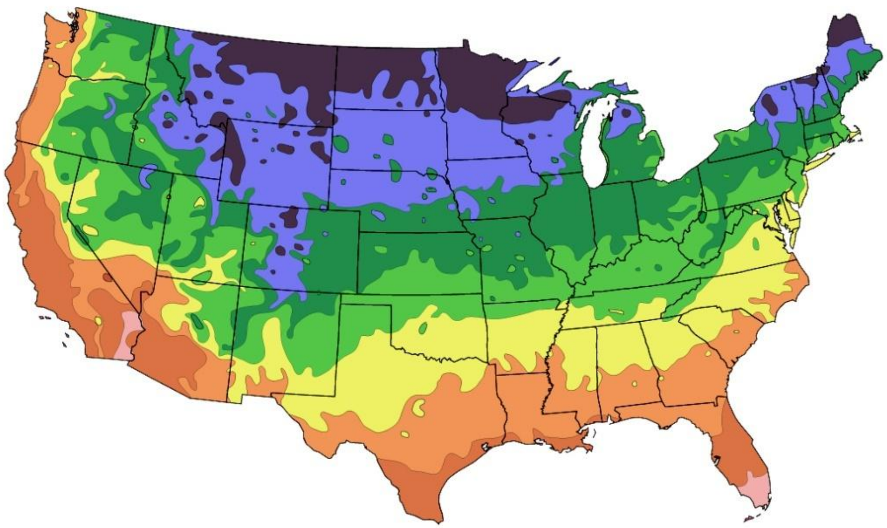
From: Flebbe et al. 2006

Examples of recent studies that link Climate Model Scenarios and Species Responses

1. Plant hardiness zones in Chicago
2. Eastern Forests
3. Native flora on the West Coast
4. Bird species in the Midwest
5. Small mammal populations in the Great Lakes
6. South Florida mangrove forests

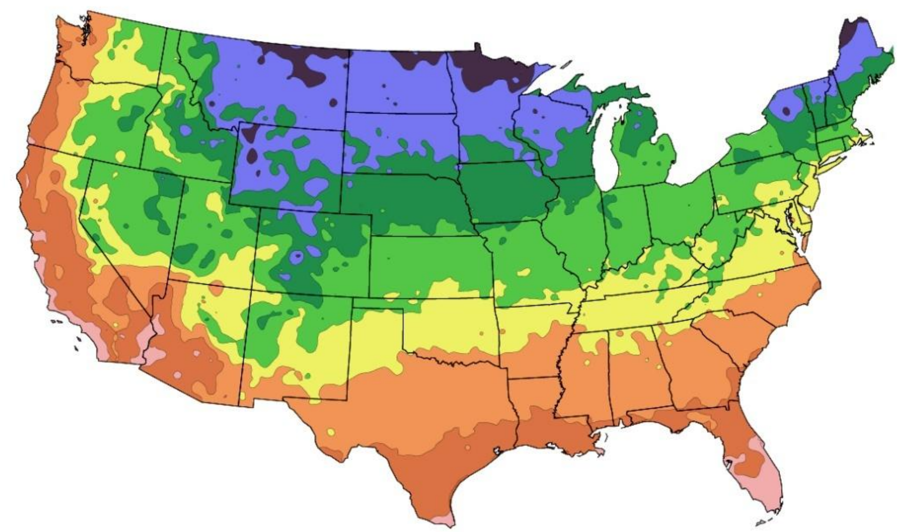
Shifting plant hardiness zones

1990 Map



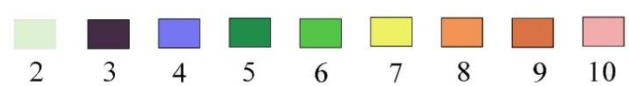
After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued Januay 1990

2006 Map



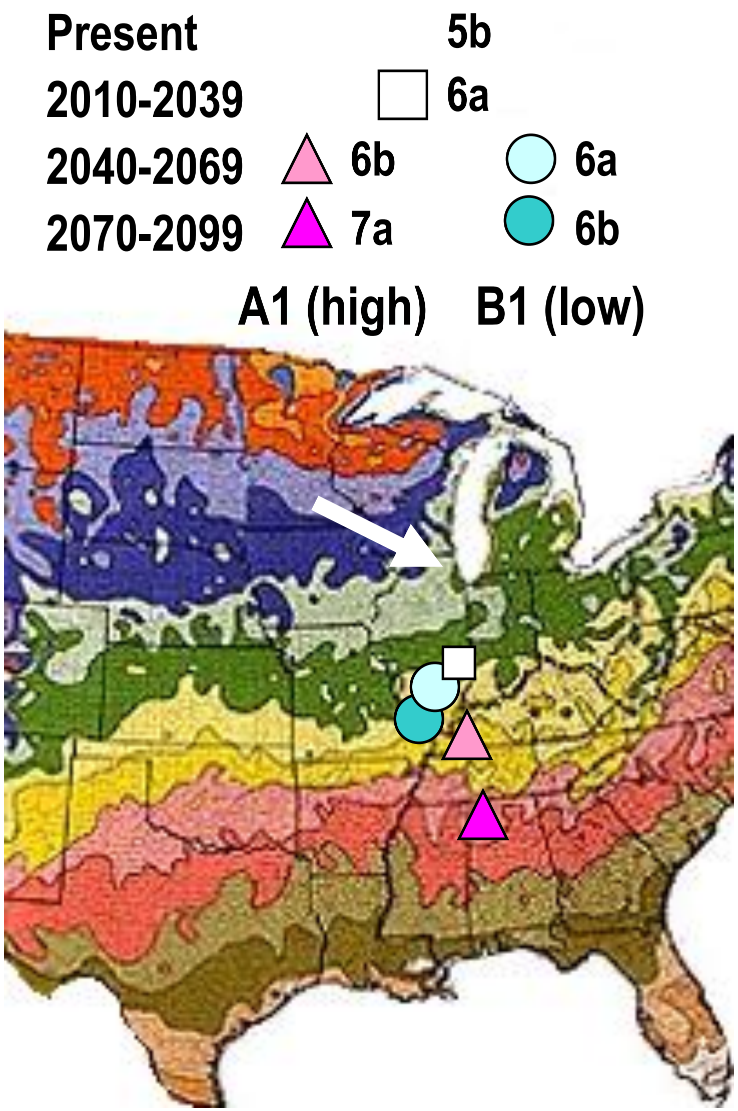
National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.

Zone



The plant hardiness zone for Dallas has *already* shifted to become more like Houston was in 1990 (just 20 yrs ago).

Projected shifts in Plant Hardiness Zones for the Chicago area

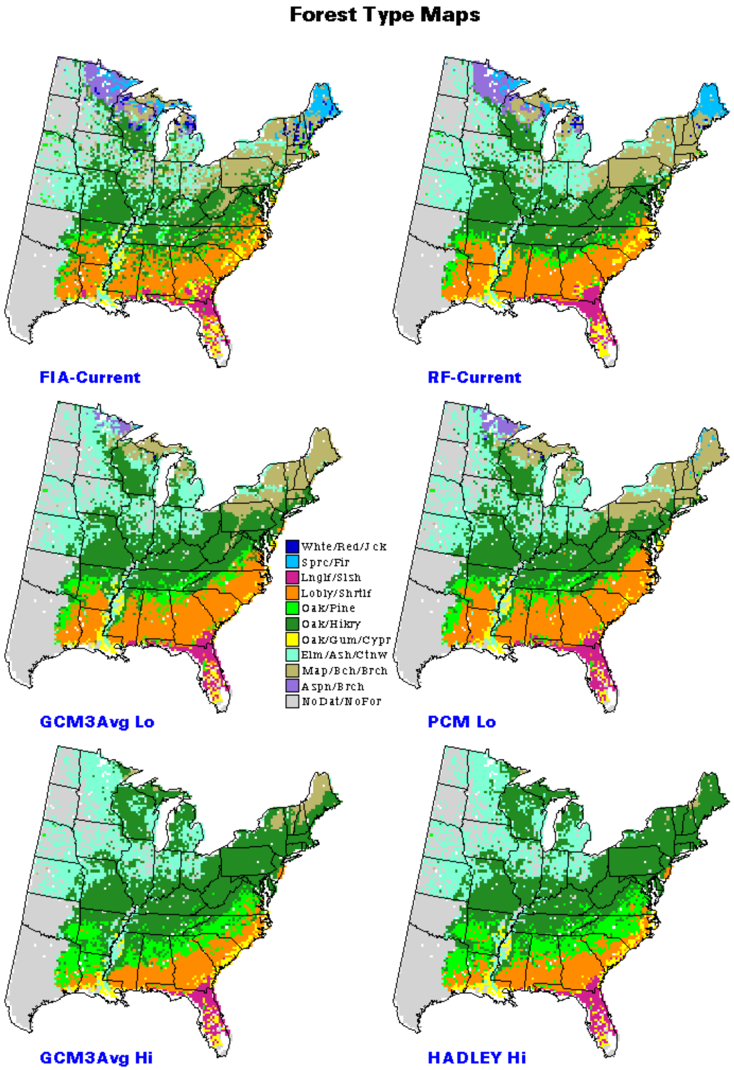


A shift of about one full zone is projected to occur every 30 years under higher emissions, and half a zone under lower emissions.

By end-of-century, Chicago could feel like northern AL under higher emissions, and southern IL/MO under lower emissions.

NOTE: "Present-day" map is based on observed temperatures from 1978 to 1986.

Projected Shifts in Eastern Forests



Summary of Potential Forest Type Changes

Shifts in suitable habitat for native species by end-of-century (2070-2099)

US Forest Service – models of tree species from the eastern United States for their potential response to climate change.

134 tree species at 20 km resolution.

- Three GCMs (Hadley, PCM & GFDL)
- Two emission scenarios (high carbon and low carbon scenarios)

USDA United States Department of Agriculture Forest Service

Climate Change Tree Atlas

Northern Research Station

Nuttall oak *(Quercus nuttallii)*

Model Reliability: (Low)

Abundance Change Maps by GCM Scenario

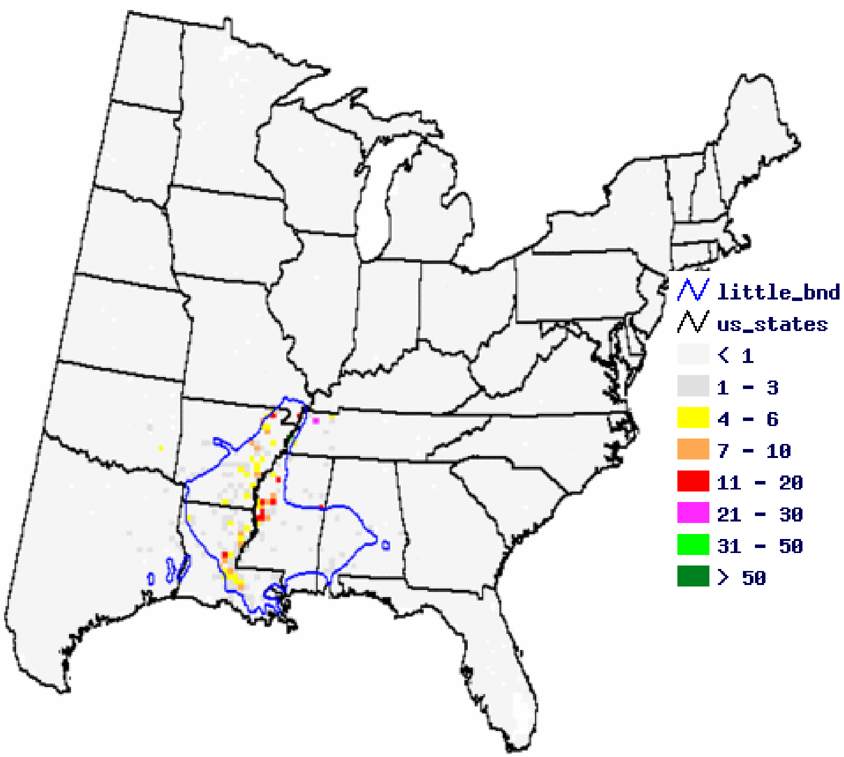
Importance value maps under five climate scenarios and two emission levels. You can also animate the scenarios to visualize change.

Animate Scenarios

Climate Scenario Menu

Choose Climate Scenario from Menu

Current FIA



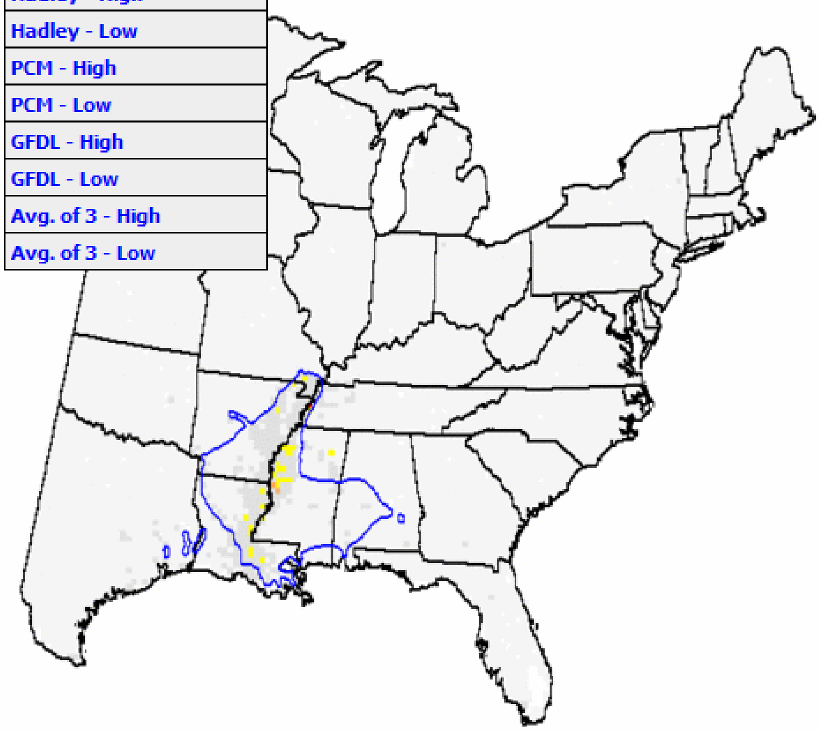
Climate Scenario Menu

- FIA Current
- Modelled Current
- Hadley - High
- Hadley - Low
- PCM - High
- PCM - Low
- GFDL - High
- GFDL - Low
- Avg. of 3 - High
- Avg. of 3 - Low

Choose Climate Scenario from Menu

Climate Scenario Menu

Current Modelled



AOU	Common Name	Scientific Name	CURPRD	PCMLO	GCM3LO	GCM3HI	HADHI	HADLO	PCMHI	GFDLLO	GFDLHI
5930	Northern Cardinal	Cardinalis cardinalis	1390.8	-9.7	-16.2	-33	-37.6	-21.4	-18.8	-16.9	-39.9
3160	Mourning Dove	Zenaida macroura	1386.2	-0.1	-2.7	-7.3	-8.1	-3.7	-2.6	-3.4	-8.1
7180	Carolina Wren	Thryothorus ludovicianus	1364.7	-40.4	-77	-147.4	-159.7	-88.1	-72.1	-96.8	-198
5870	Eastern Towhee	Pipilo erythrophthalmus	1353.7	-167.1	-246.7	-330.4	-328.5	-261.2	-238.1	-260.3	-390.9
7030	Northern Mockingbird	Mimus polyglottos	1347.7	9.4	4.8	-7.7	-10.7	3.3	4.4	2.7	-13.3
2890	Northern Bobwhite	Colinus virginianus	1323.5	38.7	44.1	45.9	44.6	45.6	44.3	44.7	45.1
4090	Red-bellied Woodpecker	Melanerpes carolinus	1322.8	-15.1	-29.3	-55.9	-60.3	-41.5	-34.5	-30.4	-65.7
7310	Tufted Titmouse	Baeolophus bicolor	1319	-55.4	-75.8	-111.7	-129.1	-104.2	-84.3	-66.5	-104.4
4930	European Starling	Sturnus vulgaris	1271.5	-102.6	-158.8	-244.7	-257.3	-205.8	-186.9	-164.7	-253.4
7050	Brown Thrasher	Toxostoma rufum	1259.7	-409.5	-512	-555.7	-548	-541.2	-504.8	-510.8	-564
4230	Chimney Swift	Chaetura pelagica	1258.1	-113	-157.5	-277.1	-306	-200.6	-203.8	-164.2	-286.8
6810	Common Yellowthroat	Geothlypis trichas	1212.6	-199.9	-256.5	-295.3	-290.1	-288.6	-266.8	-257.8	-307.5
5980	Indigo Bunting	Passerina cyanea	1176.2	-162	-232.2	-315.1	-335.9	-281.6	-262.8	-226.8	-269.5
7550	Wood Thrush	Hylocichla mustelina	1108.6	-157.5	-254.5	-351	-343.5	-298.9	-277.7	-253.3	-326.4
6110	Purple Martin	Progne subis	1044.4	102.3	122.9	114.8	124.4	133.3	122.4	115.2	110.8
5060	Orchard Oriole	Icterus spurius	1016.5	-182.6	-304.8	-433.8	-456	-375.7	-343.5	-313.7	-437.7
7610	American Robin	Turdus migratorius	886.6	-122.8	-207.2	-281.5	-314.3	-296.3	-259.5	-182.1	-205.2
4770	Blue Jay	Cyanocitta cristata	820.7	-200	-230.4	-233.7	-224.9	-233.1	-223.5	-230.1	-278.1
7040	Gray Catbird	Dumetella carolinensis	805.1	-206	-302.3	-370.8	-403.8	-362.7	-324.9	-289.9	-287.2
4160	Chuck-Wills Widow	Caprimulgus carolinenis	745.5	175.2	191.6	185.4	158	186.8	186.7	196.8	156
6220	Loggerhead Shrike	Lanius ludovicianus	649.7	104.5	127.2	154	163.5	146.8	149.6	123.9	148.6
3390	Red-shouldered Hawk	Buteo lineatus	638.6	100.8	123.5	146.5	140.5	141.5	146.7	111.8	103.9
2001	Cattle Egret	Bubulcus ibis	590.1	265.8	359.9	438.9	442	401.7	383	367.7	447.8
5290	American Goldfinch	Carduelis tristis	558.8	-224.8	-285.7	-340.2	-337.6	-318.6	-295	-288.4	-346
1940	Great Blue Heron	Ardea herodias	503.4	70	104.1	147.4	146.5	106.2	99.6	110.6	192
3260	Black Vulture	Coragyps atratus	461.4	62.9	98.4	142.8	158.5	146.9	125.9	76.7	129.8
6740	Ovenbird	Seiurus aurocapillus	405.2	-202.6	-225.2	-228.4	-218.9	-230.2	-224	-221.1	-221.1
6770	Kentucky Warbler	Oporornis formosus	390.6	102.1	120.4	118.5	151.4	143.6	126.3	110	111.6
5810	Song Sparrow	Melospiza melodia	372.6	-192.1	-237.8	-276.2	-271.7	-259	-239	-239.2	-259.3
4200	Common Nighthawk	Chordeiles minor	371.3	112.3	182.2	276.8	297.9	233.6	218.1	179.5	256.1
3200	Common Ground-Dove	Columbina passerina	362.8	41.4	95.5	196.8	246.2	168.5	142.3	71.8	171.2
1960	Great Egret	Ardea alba	362.3	145.5	200.2	285.5	291.4	230.8	219.7	203.1	303.7
2000	Little Blue Heron	Egretta caerulea	349.9	191.3	245	297	307.4	266	251.1	245.7	315.2
5460	Grasshopper Sparrow	Ammodramus savannarum	319	-167.4	-194.4	-196.8	-194.6	-206.7	-196.7	-189.7	-138.5
5750	Bachmans Sparrow	Aimophila aestivalis	287.9	93.5	132.9	180.6	211.1	177.3	179.2	114.5	139.2
6360	Black-and-white Warbler	Mniotilta varia	217.4	91.4	123.7	139.7	152.7	123.2	125.1	122.7	147.1
6010	Painted Bunting	Passerina ciris	117	325.6	430.9	544.1	545.4	472.7	431.5	448.1	622.4
6120	Cliff Swallow	Petrochelidon pyrrhonota	39.3	52.9	101.6	174.5	183.3	141.9	120.3	104.5	183.1
6040	Dickcissel	Spiza americana	29	202.9	285.1	373	377.4	274.7	266.1	319.4	463.9
4430	Scissor-tailed Flycatcher	Tyrannus forficatus	2	64.1	108.6	174.8	188.2	119.7	111	120.9	209.1

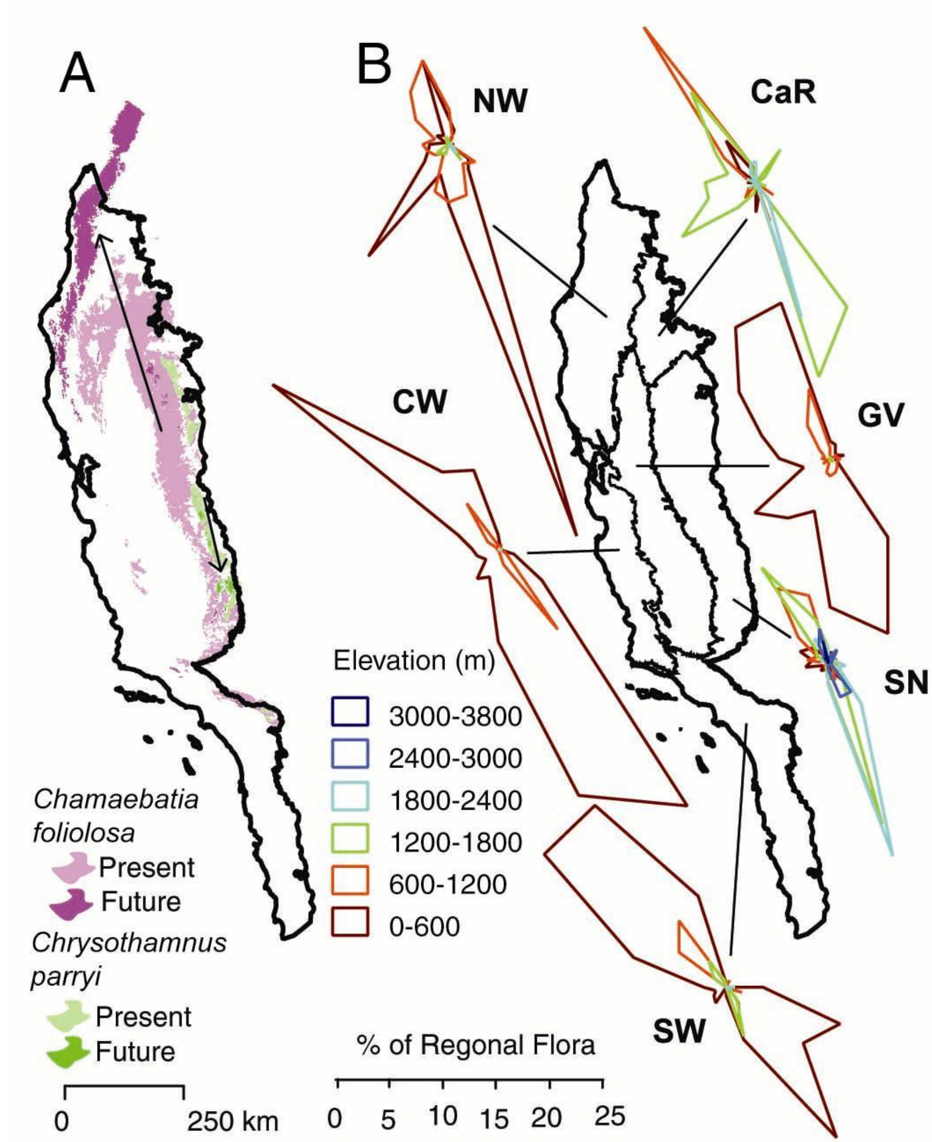
Native flora on the West Coast

California's varied terrain could cause species to move in very different directions

2/3 of 5,000 endemic species likely to experience range reductions greater than 80%

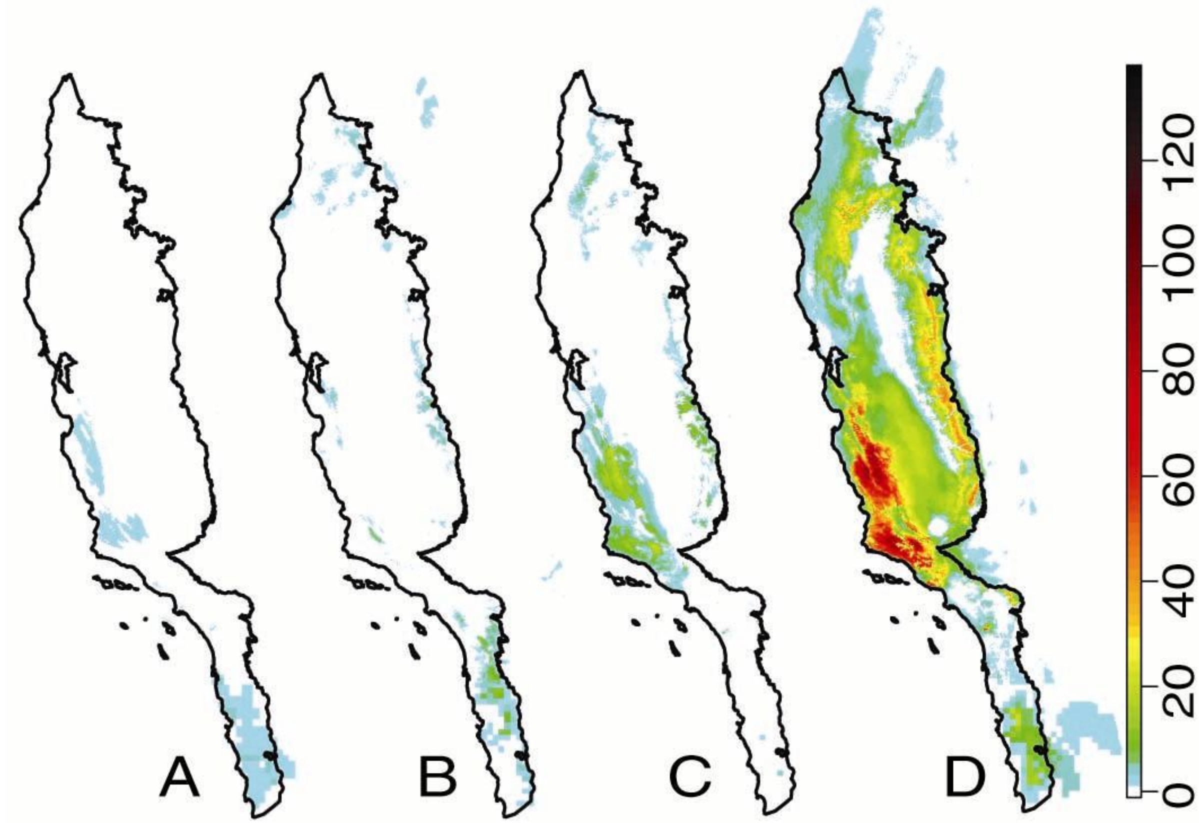
Refugia likely to form where species undergoing severe range reductions will persist

(Based on simulations by Loarie, Hayhoe et al, 2008)



Native flora on the West Coast

The greater the climate change, the greater the magnitude of species extinctions expected



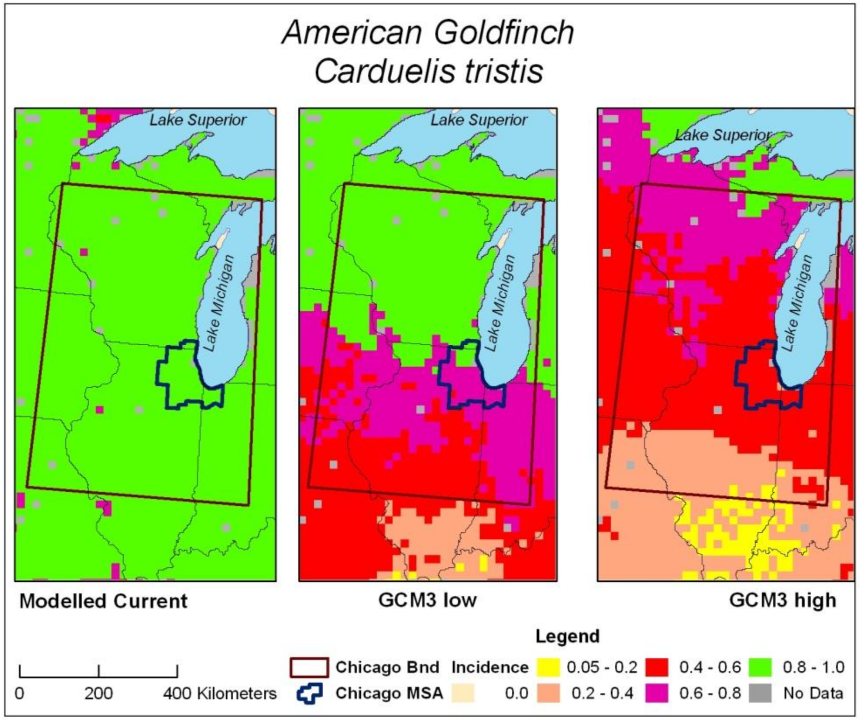
Higher emissions

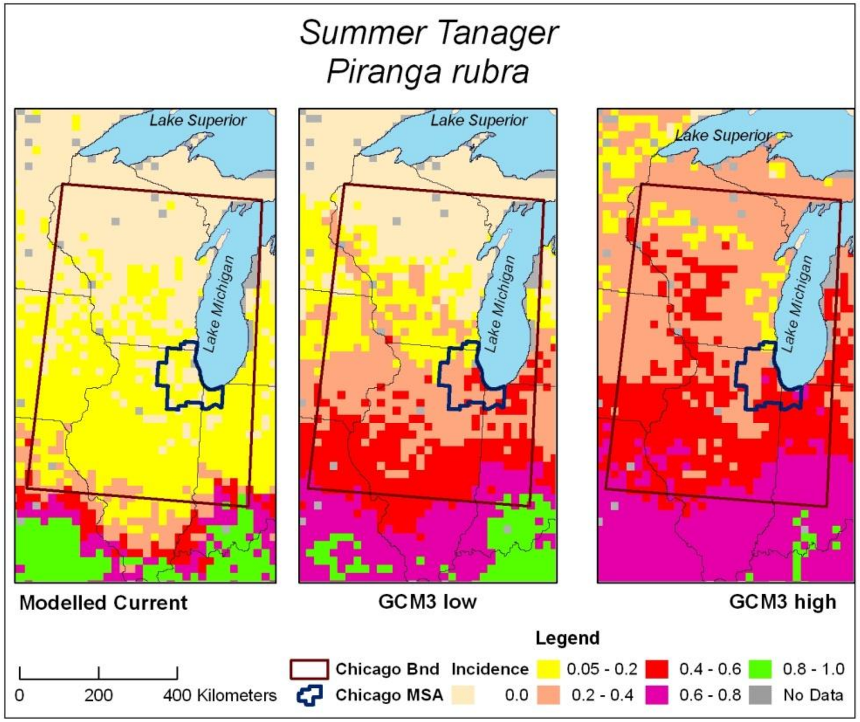
Present distributions of species expected to become extinct within 80 years

(Loarie, Hayhoe, et al., 2008)

Bird Species in the Midwest

Projected distribution and abundance under climate change for one species that will likely undergo a large decrease from the Chicago region, the American goldfinch, and one that will likely undergo a large increase, the Summer Tanager.





Projected to arrive

Blue grosbeak

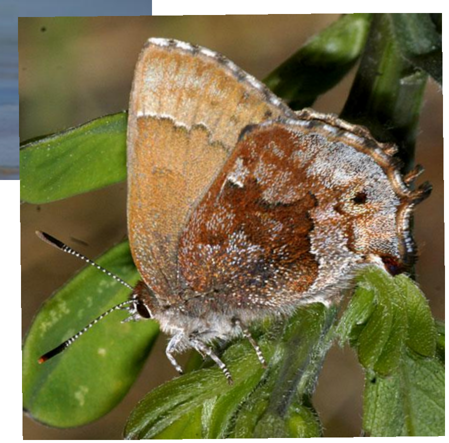
Mississippi kite

Diana fritillary

Projected to disappear

House finch

Spotted sandpiper



Frosted elfin

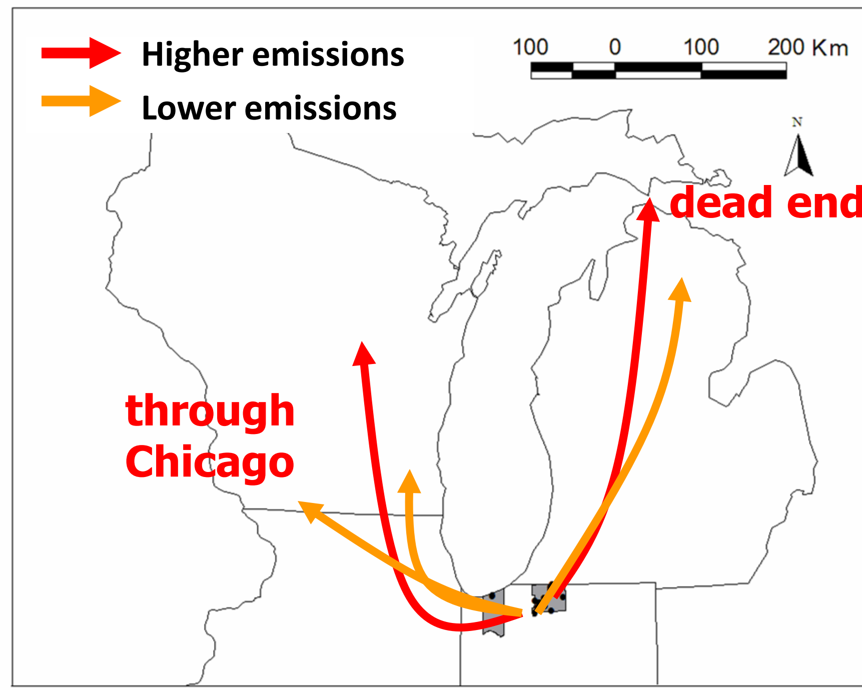
(Matthews et al. 2004; Opler et al. 2006)

Small Mammal Migration

Franklin's Ground Squirrel - *Spermophilus franklinii*

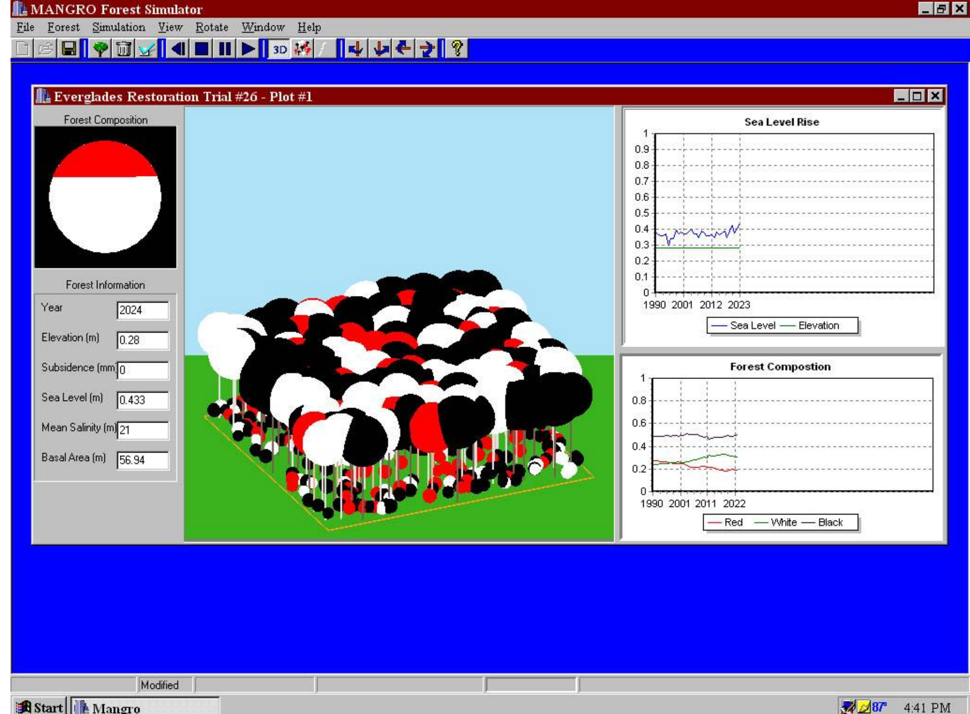
- Formerly common prairie species in IL and IN
- 99% of habitat lost after settlement of prairies
- Now on state endangered species list

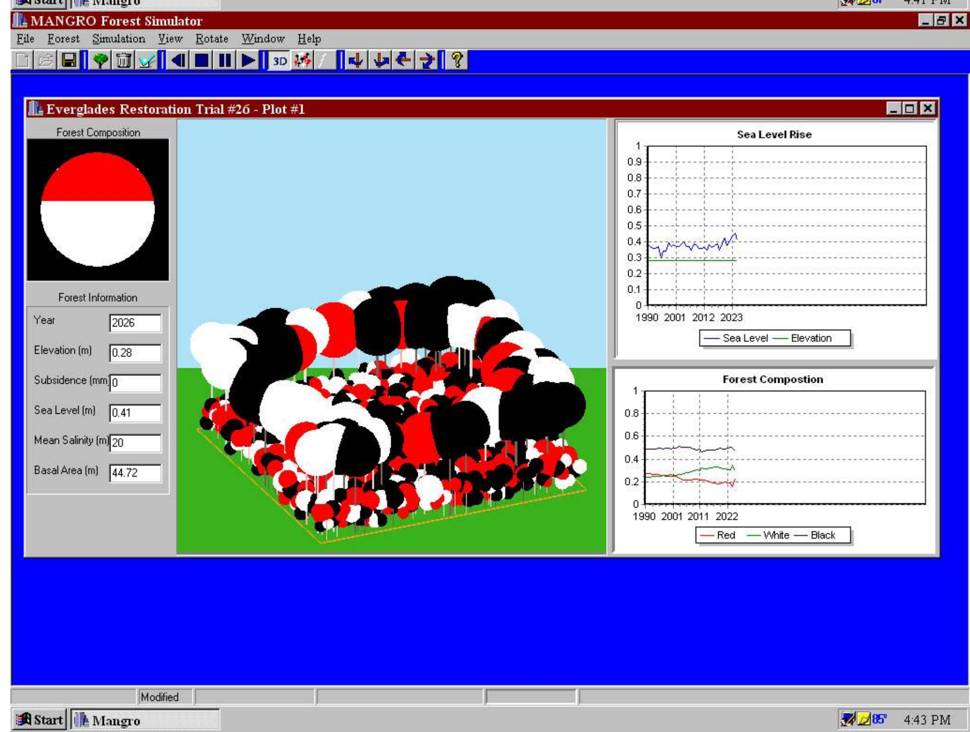
- Temperature-sensitive species, hibernates from Sept to April
- By end-of-century, climate changes are likely to force small mammal migrations either:
  - NE into Michigan, potentially dead-ending at Straits of Mackinaw
  - NW through the Chicago Metro & suburban region (nearly impassable)



South Florida Mangroves

Selva/MANGRO Model





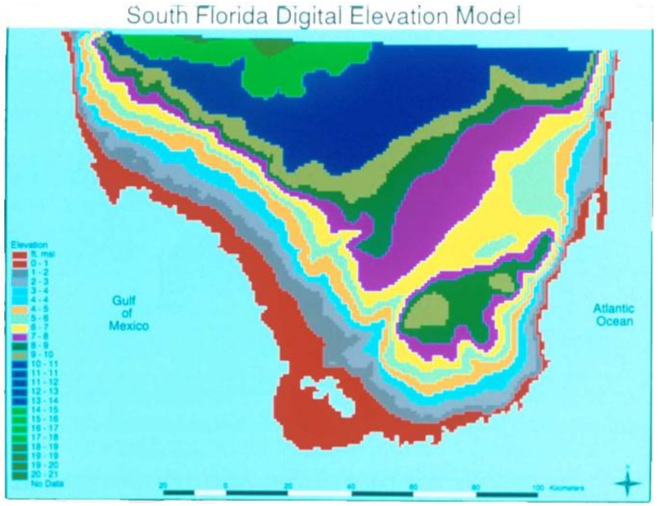
Disturbance Agents

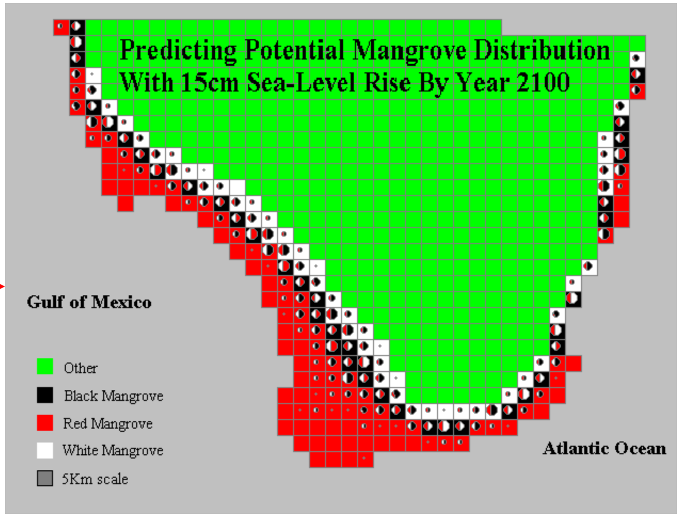
Hurricanes
Lightning

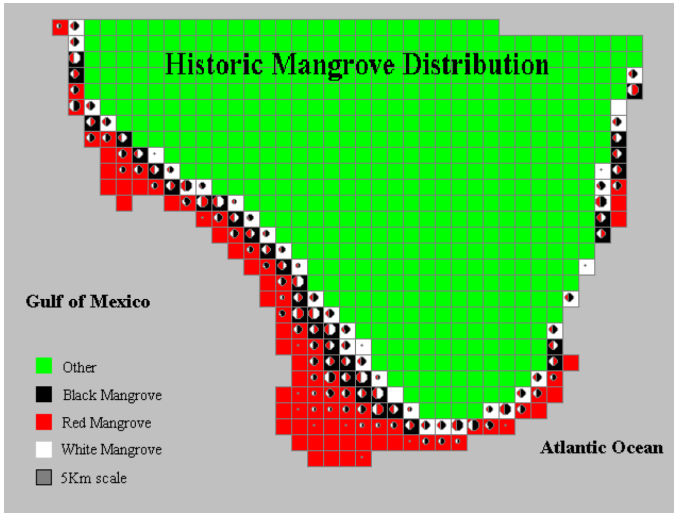
Forcing Functions

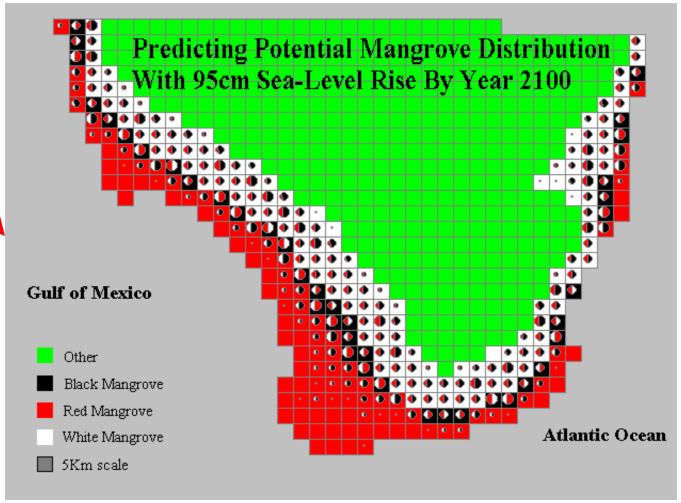
Sea-level Rise
Freshwater Flow

SELVA/MANGRO Forecasts









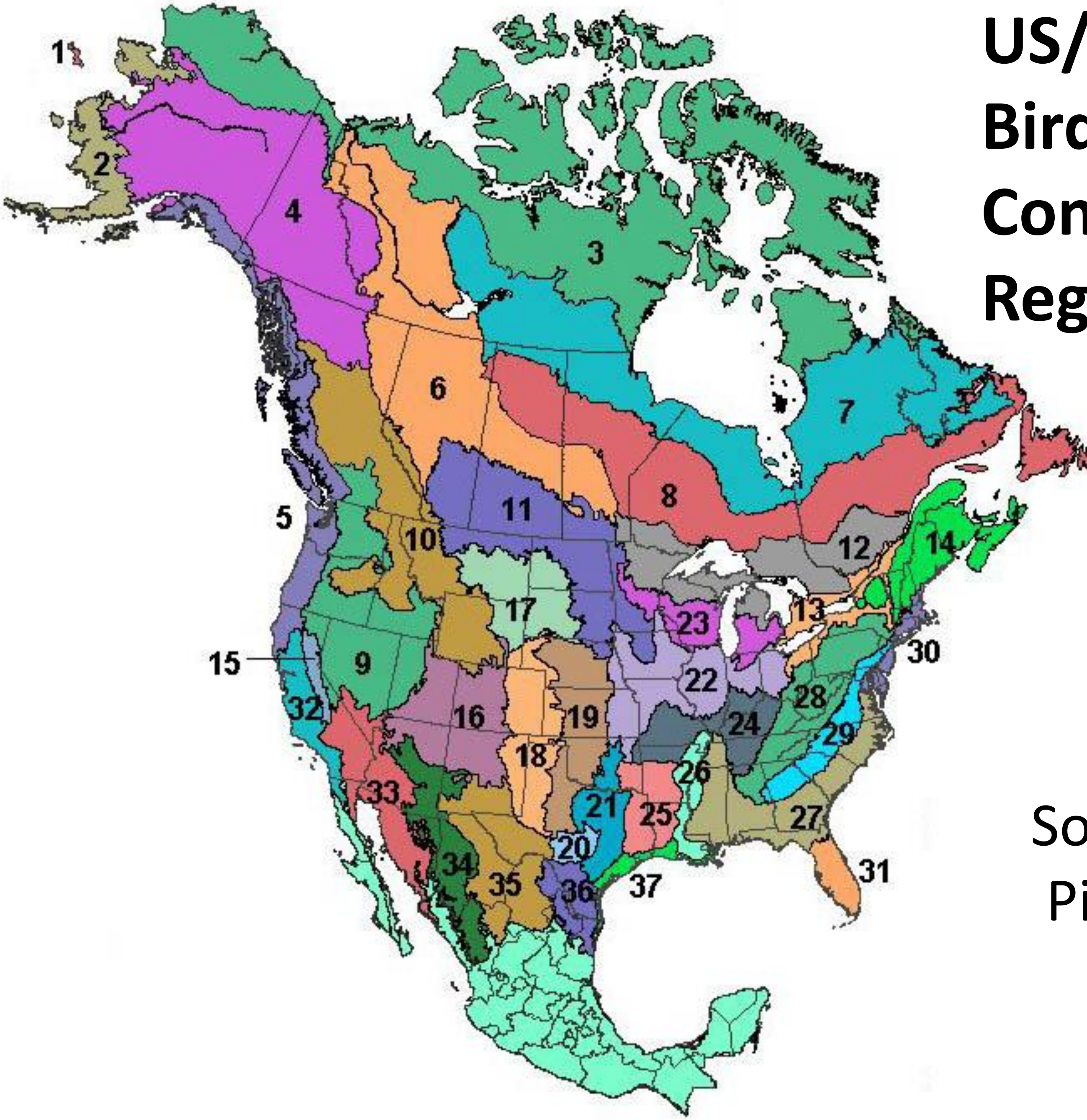
How will climate change affect other plant and animal species in North America?

- Invasive species
- Aquatic species
- Amphibians and reptiles
- Ungulates
- Pests and pathogens
- Waterfowl
- Endangered plants and animals

Managing Fish and Wildlife in a Changing Climate: Scientific Obstacles

- Interactions are difficult to predict and simulate – e.g., invasive species, differential response to climate drivers
- Climate models simulate averages, not extreme events that structure ecosystems
- Intrinsic and extrinsic thresholds are not captured by current ecological models, not even known for most species
- Scale of knowledge does not match scale of management
- Uncertainty in forecasting can be reduced, but will always exist
- Poorly developed coordination mechanisms to link efforts
- No methodical, systematic approach for assessing impacts and supporting adaptation
  - NOAA Climate Services concept – border to border, consistent quality and scale, forecasts and monitoring components, partner driven.
  - Need a comparable approach for fish and wildlife

US/Canada Bird Conservation Regions



Southeastern Pilot Project

Southeast BCR Project Objectives

1. Estimate the historic rate of landscape-level change in **Land Use And Land Cover** in relation to change in climate parameters.
2. Use historic data to estimate the rates of change in **Bird Distribution** in relation to changes in climate and landscape parameters.
3. Use appropriately-scaled climate models to project the effects on **Regional Climate**.
4. Use regional climate predictions to predict the effects of climate change on **Landscapes and Bird Distributions**
5. **Test prototype for other BCRs**

Climate-related tasks and products, Year 1:

1. Assess observed changes in climate since 1900 and 1970 for each BCR in the Southeast
2. Obtain existing statistically and dynamically downscaled model output fields
3. Extract relevant variable fields for the geographical region of interest
4. Identify relevant impact indicators and resolve climate metrics to be projected
5. Derive historical simulations and future projections of climate metrics from statistically and dynamically downscaled fields
6. Assimilate results into eight Southeastern Bird Conservation Regions
7. Compare projections from statistically vs. dynamically downscaled projections to evaluate the relative strengths and weaknesses of each approach
8. Maps showing projected changes in climate metrics across the Southeast region for three future time periods (2010-2039, 2040-2069, 2070-2099)

Partnerships sought

- Steering Committee – NCCWSC, State of Tennessee, FWS
- FWS R4 – GIS lab
- Other SE States, agency personnel interested in or trained in modeling
- NOAA and Forest Service
- NEON/LTER/NPN

Broad goals

- explore approaches for assessing impacts on fish and wildlife
- experience for USGS coop units, FWS, FS, and States
- building capacity to enhance fish and wildlife conservation